Scanning-HIS / AIRS / MODIS IR Intercalibration

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SSEC

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Topics

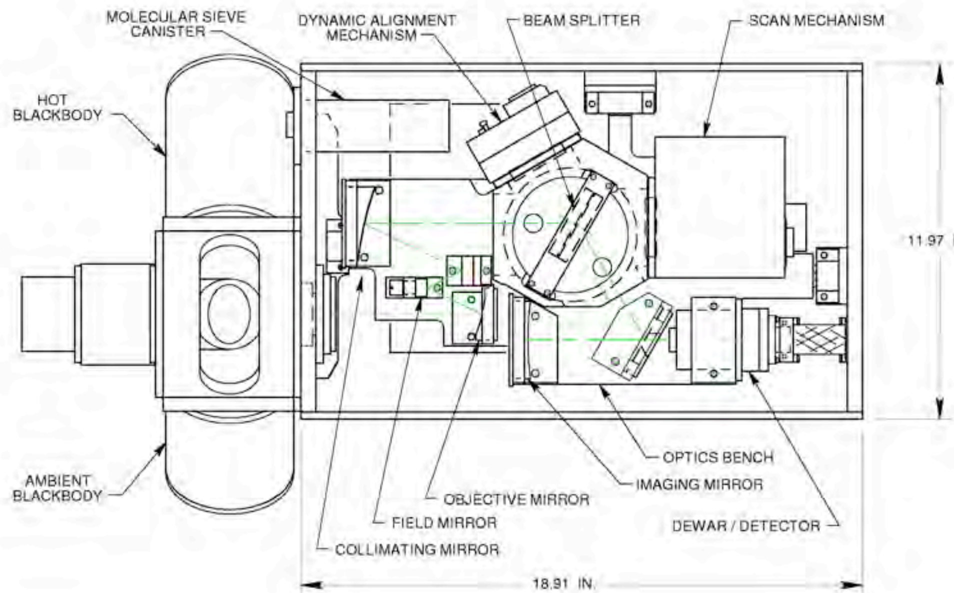
- Scanning-HIS Introduction
- Satellite validation with the Scanning-HIS
  - AIRS and IASI underflight examples
- Broadband sensor intercomparison examples
  - AIRS and MODIS on EOS Aqua
  - Geo/Leo Intercal using AIRS
- CLARREO Intercalibration Study

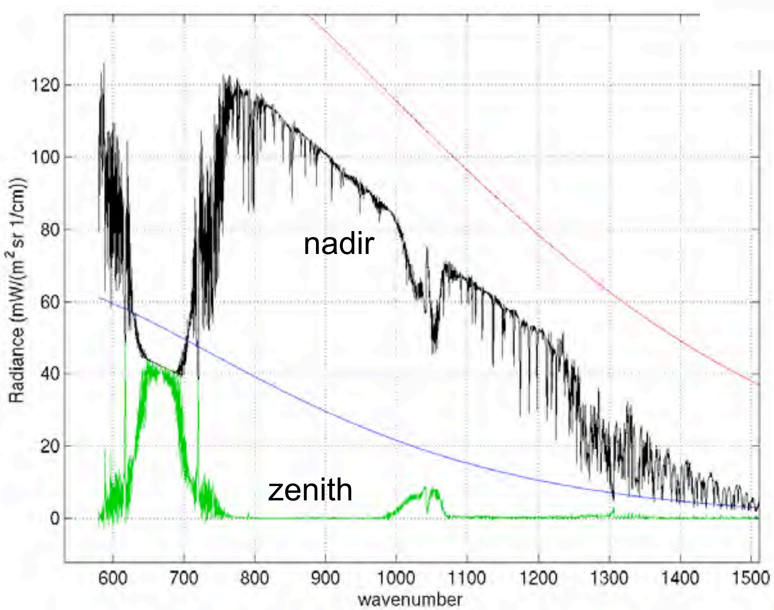
Relevance to CLARREO

- **Satellite validation with the Scanning-HIS**
  - ***Demonstrated accuracy consistent with engineering estimates of ~0.2K 3-sigma, contributing to the technical readiness of CLARREO***
  - ***An important component of a compliment of validation efforts required for providing independent and rigorous post-launch evaluations of CLARREO***
- **Broadband sensor intercomparison examples**
  - ***Example uses/benefits of having/continuing high spectral resolution IR benchmark measurements***
- **CLARREO Intercalibration Study**
  - ***Given a mission constellation selected for producing the primary CLARREO climate products, provide an estimate the spatial and temporal colocation errors associated with performing intercalibration with a sun-synchronous sounder via SNOs***
  - ***Estimate the CLARREO sensor noise required for accurate intercal via the same SNOs***

Scanning-High resolution Interferometer Sounder

- HIS and AERI heritage
- 1 cm MaxOPD
- 580-3000 cm^{-1} coverage with three spectral bands
- 100 mrad FOV (~2 km diameter from 20 km)
- programmable cross track downward and zenith viewing
- 1998 to present on NASA ER-2, Proteus, and NASA WB-57
- In-field calibrated spectra



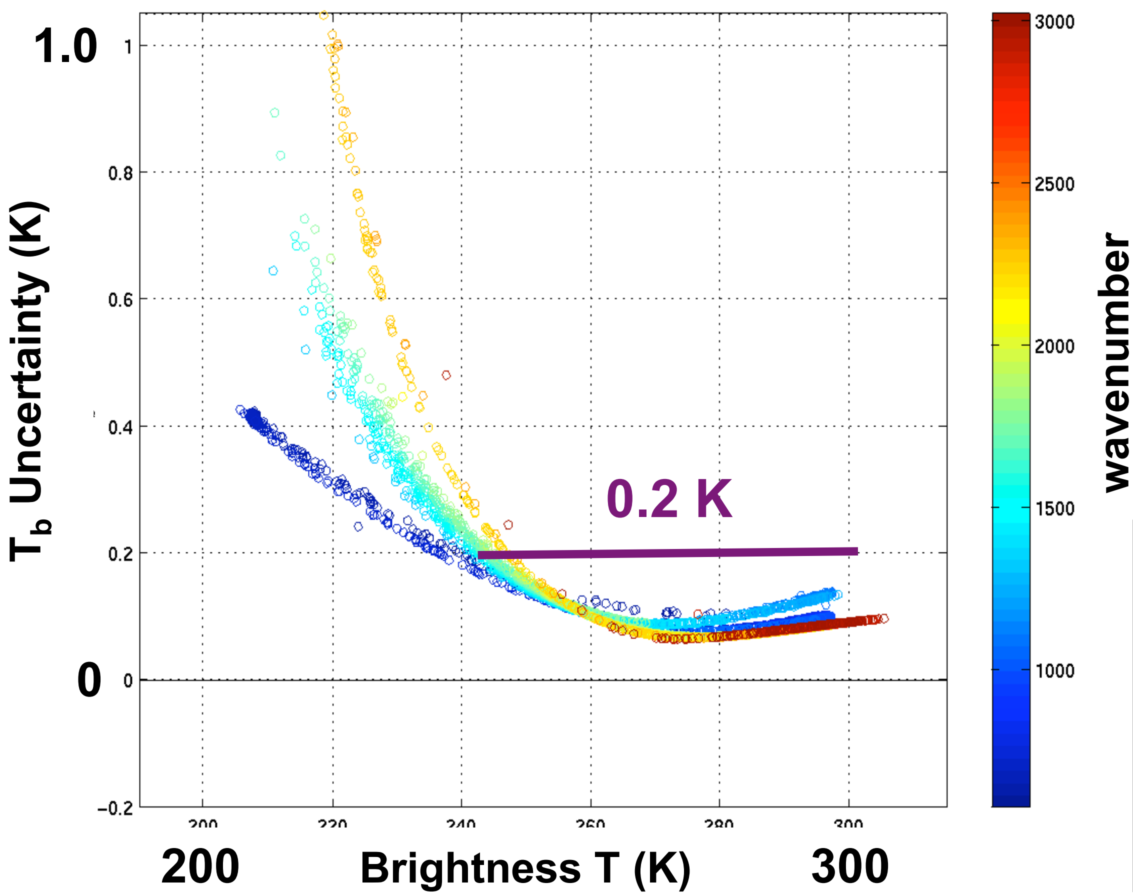


S-HIS on WB-57 wing pod

S-HIS Absolute Radiometric Uncertainty

for a typical Earth scene spectrum

****Formal 3-sigma absolute uncertainties, similar to that detailed for AERI in Best et al. CALCON 2003**



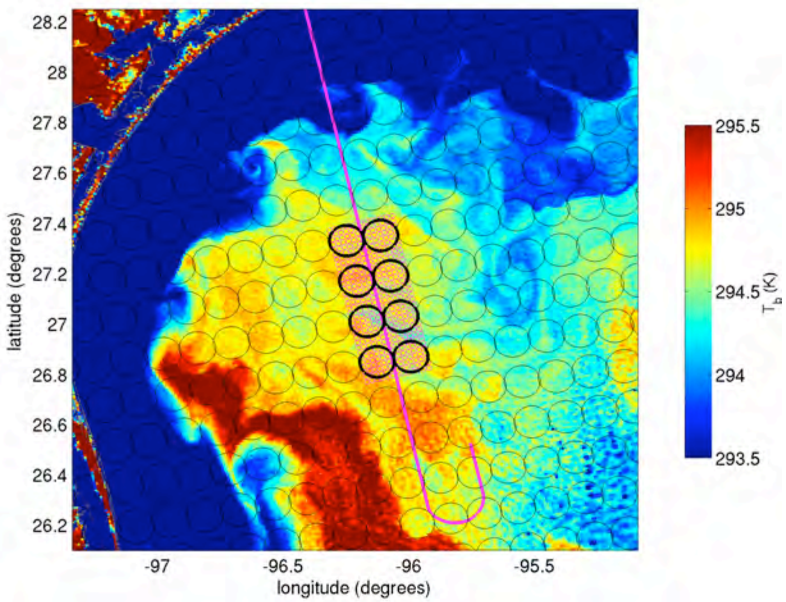
T_{ABB}= 260 K
T_{HBB}= 310 K

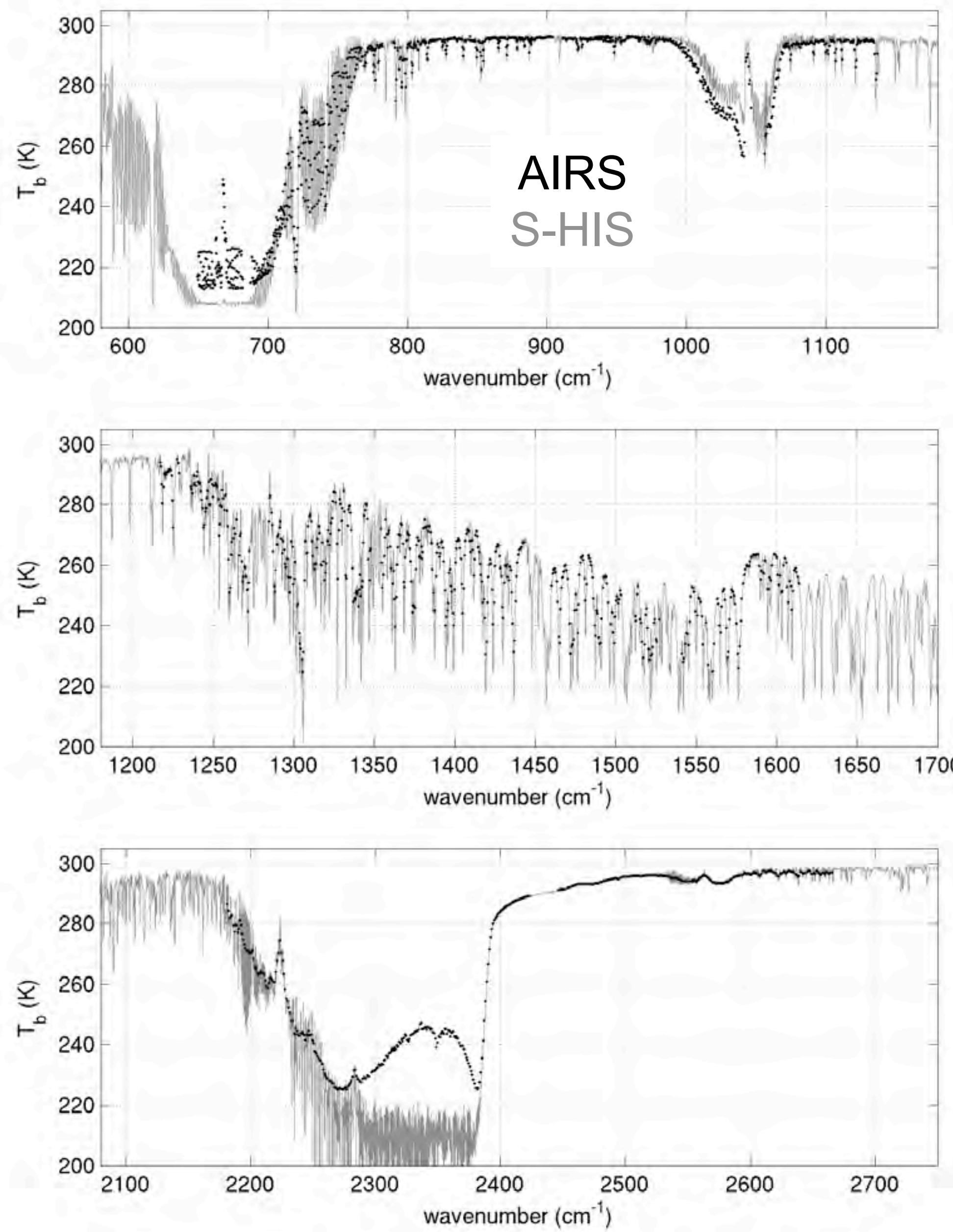
σT_{BB} = 0.10 K
$\sigma \varepsilon_{BB}$ = 0.0010
σT_{refl} = 5 K
10% nonlinearity

Confirmed with recent end-to-end radiance tests with NIST TXR

AIRS underflight
21 November 2002
Gulf of Mexico
Daytime

AIRS / S-HIS comparison, without accounting for viewing geometry or spectral resolution/sampling differences:



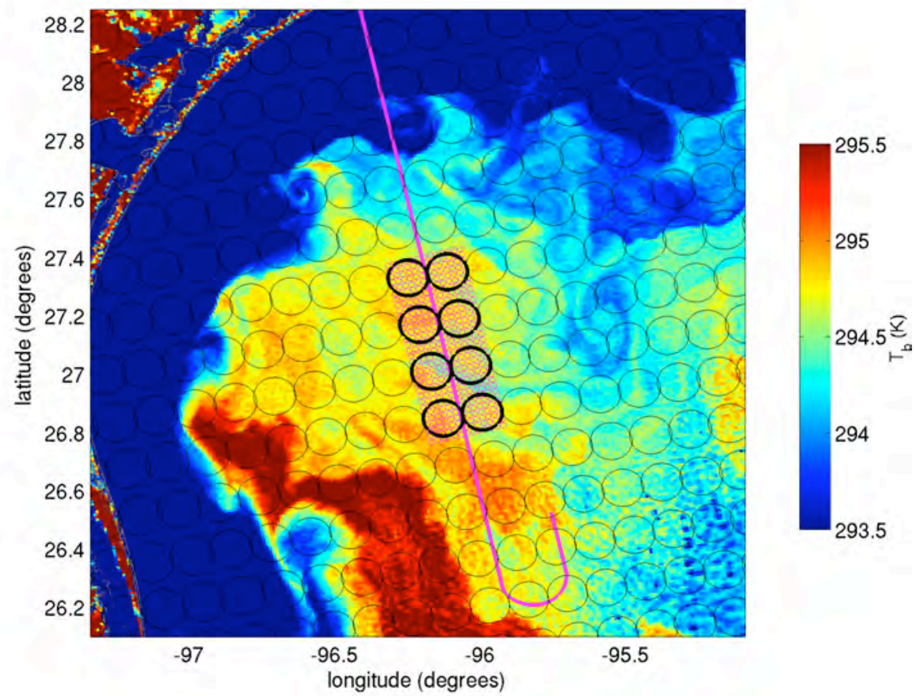


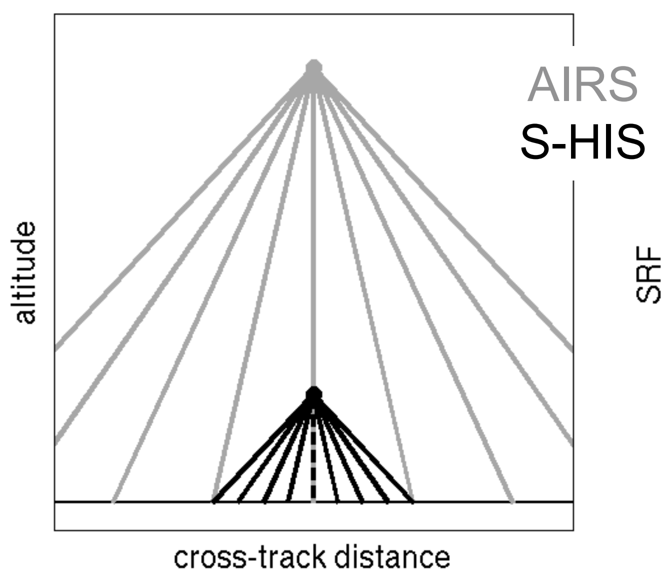
8 AIRS FOVs (noise filtered) and 416 collocated S-HIS FOVs selected for comparison.

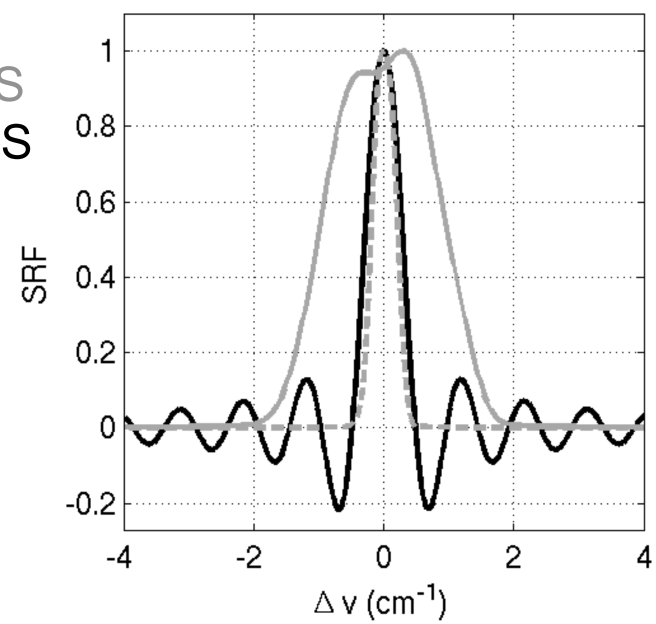
AIRS at 705 km,near nadir

S-HIS at 20.0 km,
13 view angles covering ±30°

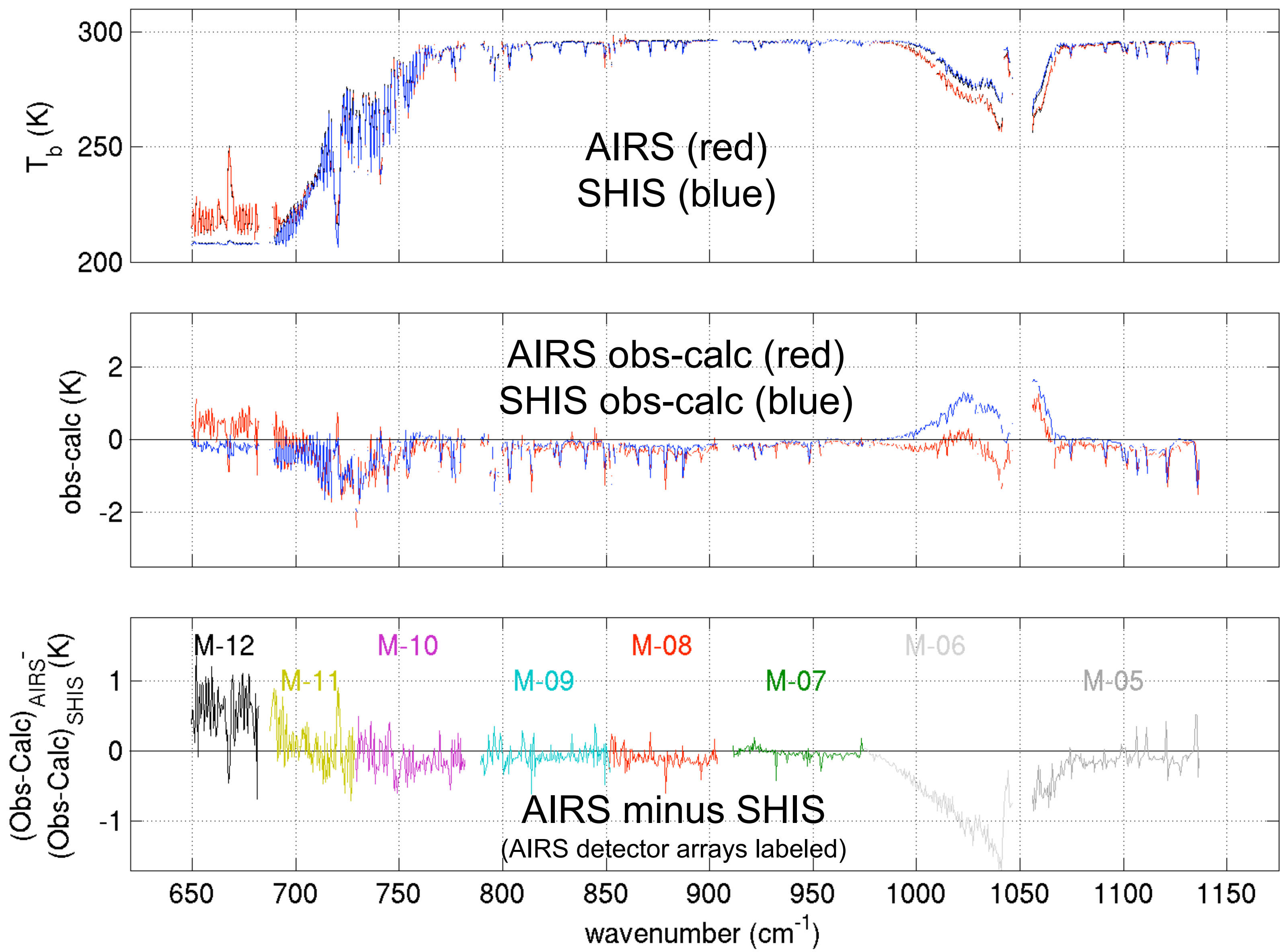
$(\mathrm{Obs}_{AIRS}-\mathrm{Calc}_{AIRS}) \otimes \mathrm{SRF}_{SHIS}$ -
$(\mathrm{Obs}_{SHIS}-\mathrm{Calc}_{SHIS}) \otimes \mathrm{SRF}_{AIRS}$



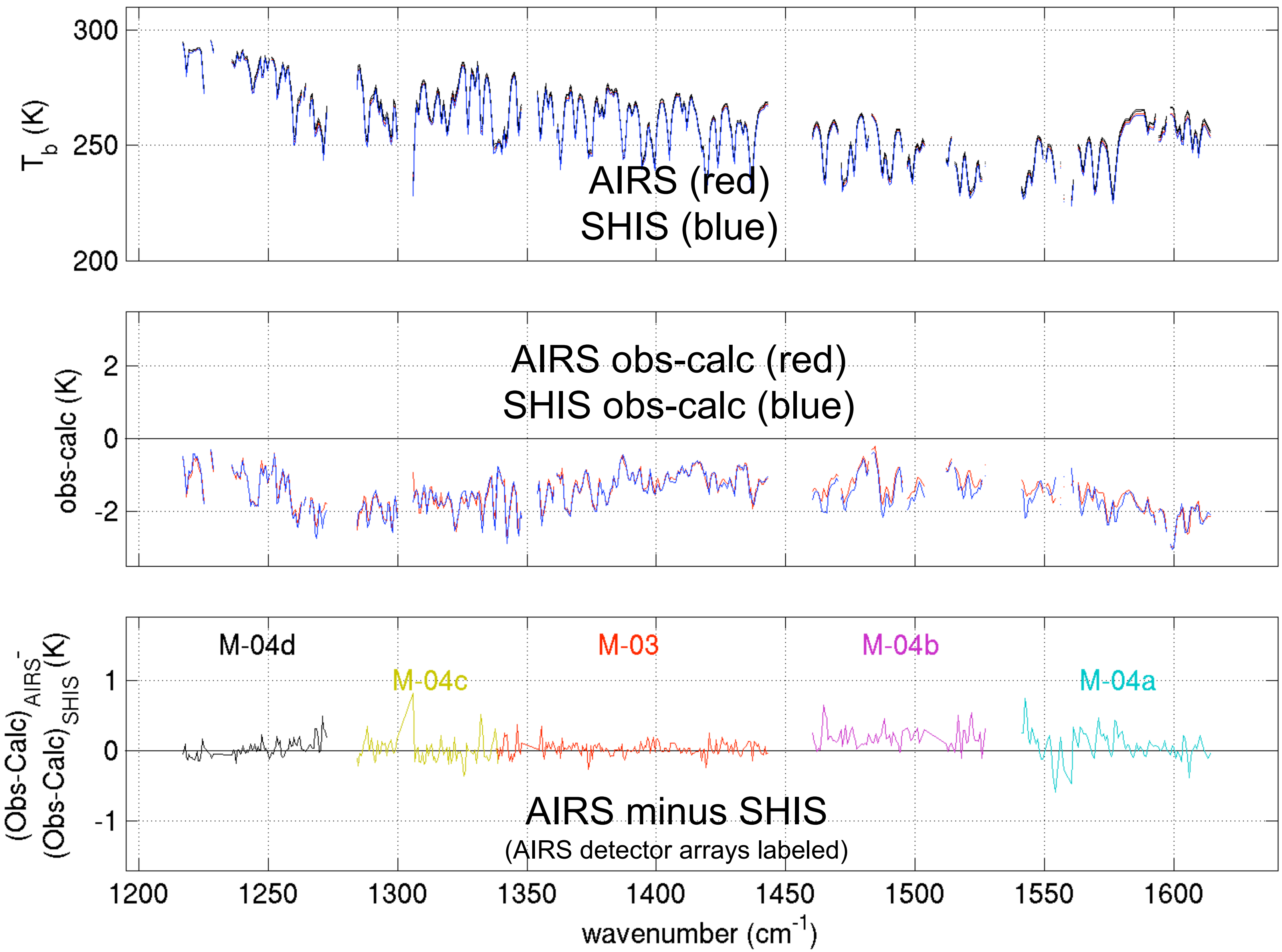




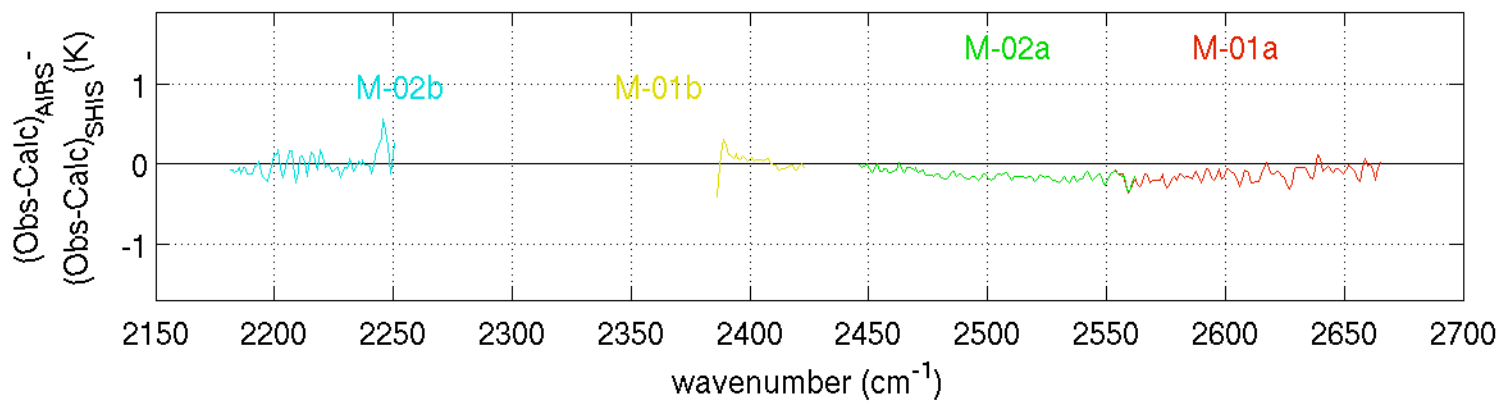
AIRS / S-HIS comparison, accounting for viewing geometry and spectral resolution/sampling differences.

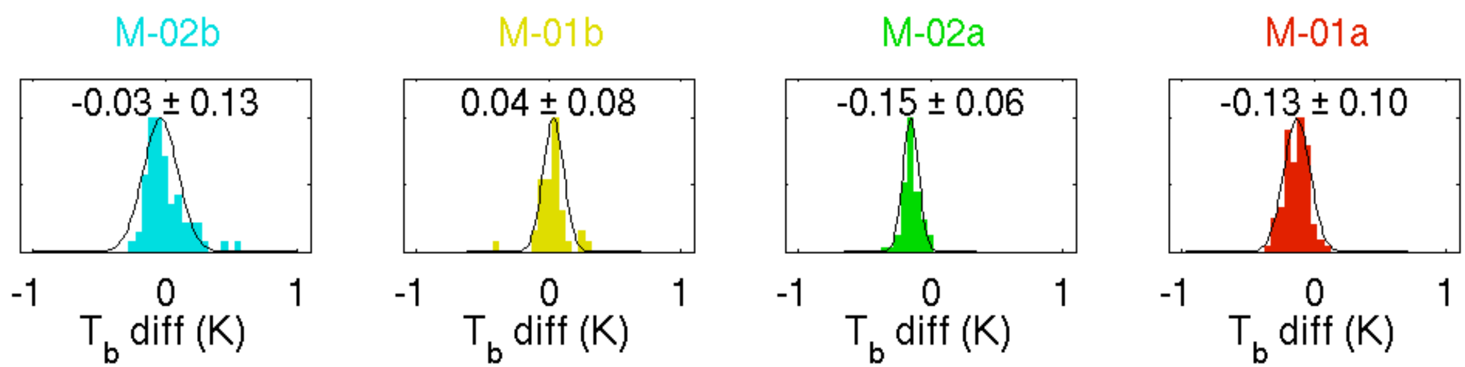


AIRS / S-HIS comparison, accounting for viewing geometry and spectral resolution/sampling differences.



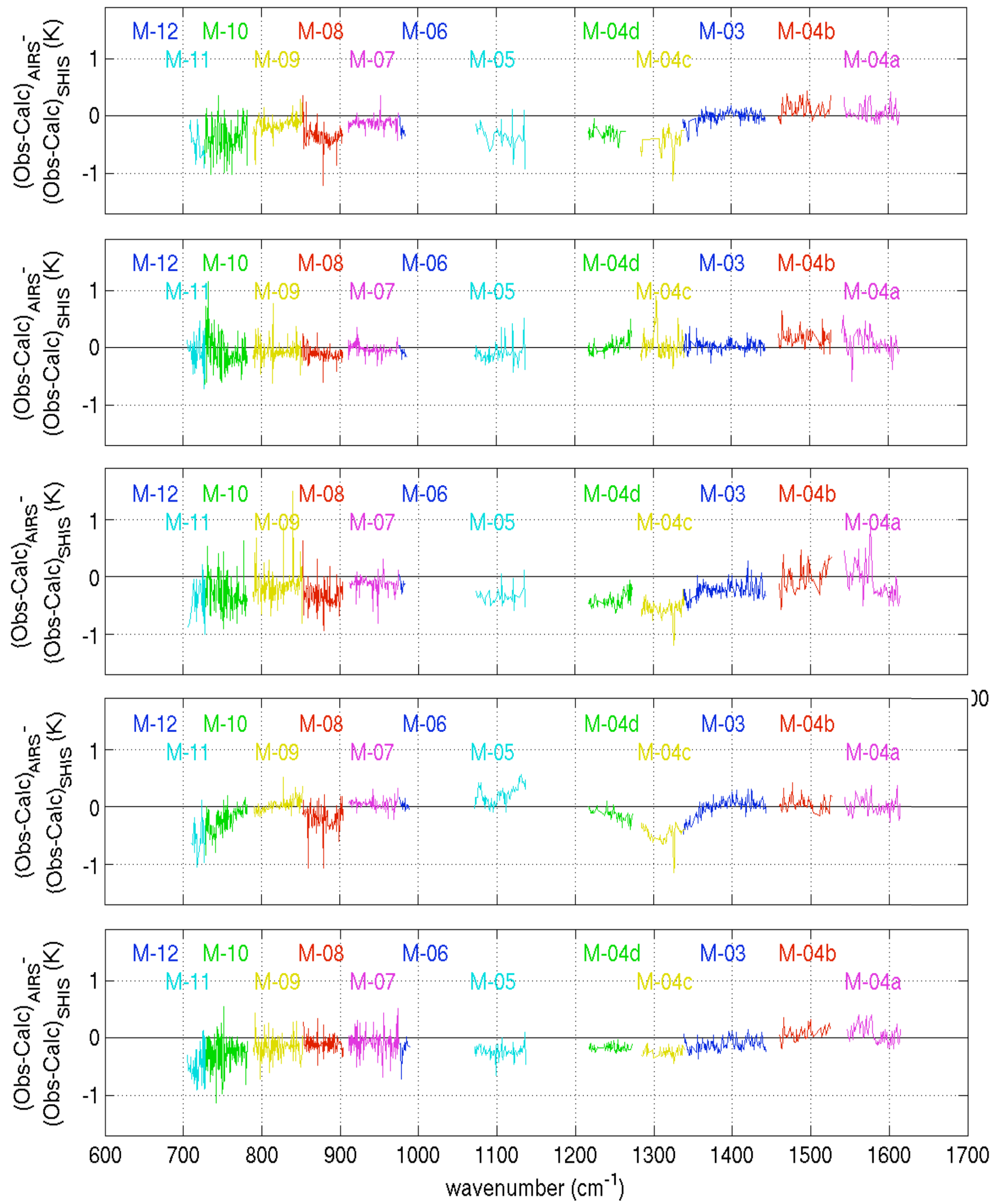
Night-time case summary: Shortwave





Other cases

- Results are remarkably good, generally within SHIS error budget
- Includes Tropical to Arctic conditions; Extends over mission life
- Provides traceable uncertainties for basis of using AIRS for satellite cross-calibration
- ~8 other cases collected to date not shown



2002.11.16 ARM-SGP

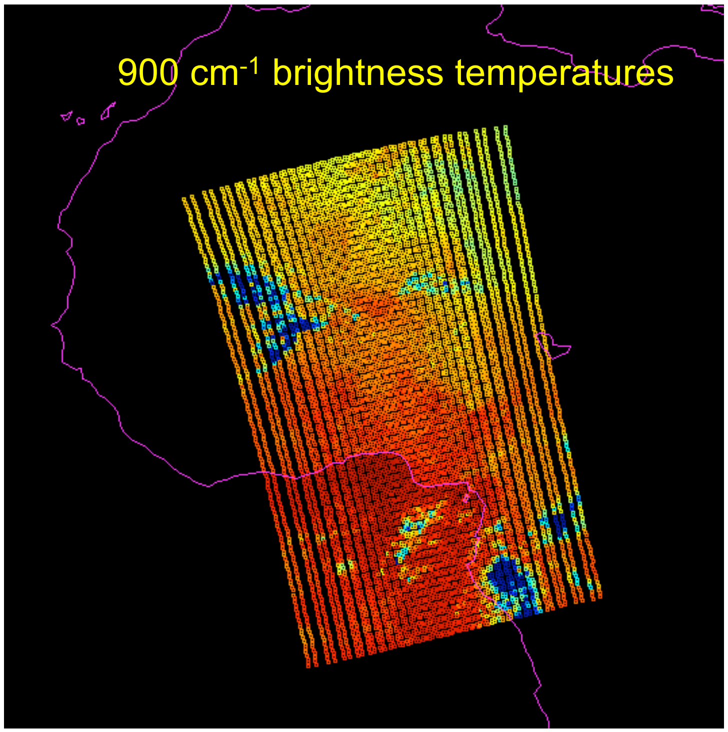
2002.11.21 Gulf of Mex

2004.09.07 Italy

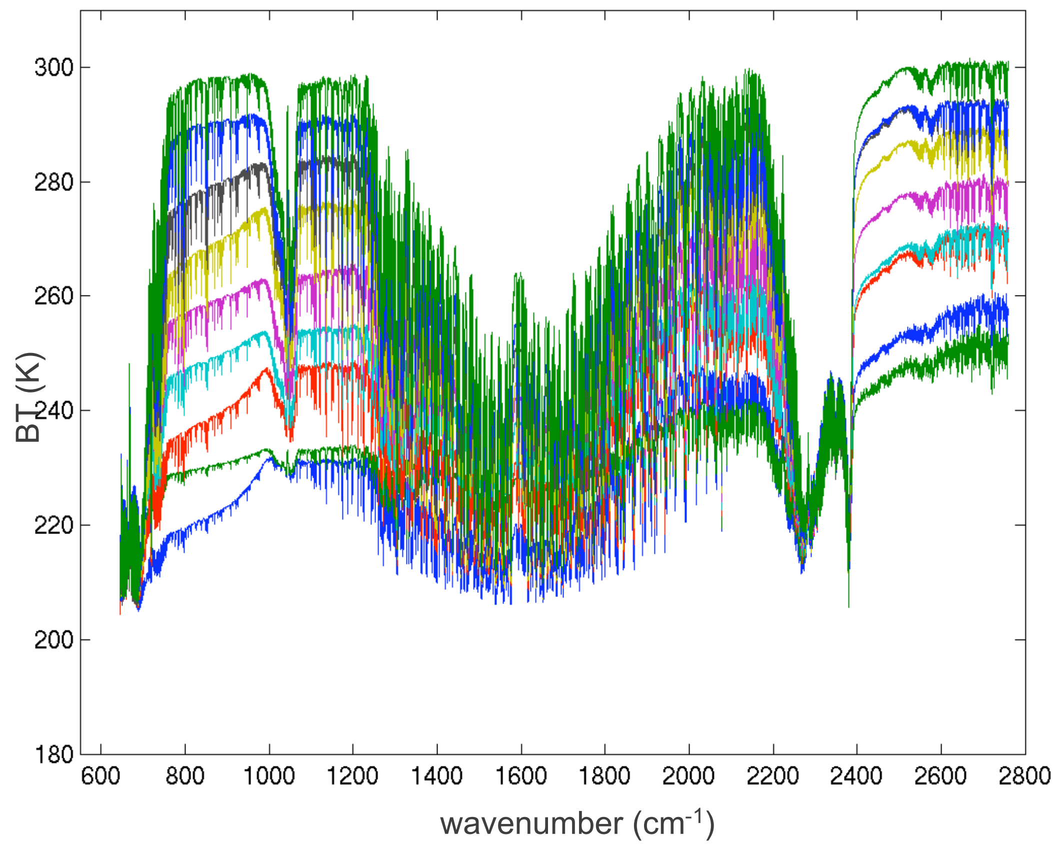
2004.10.21 Arctic stratus

2006.01.17 Tropical

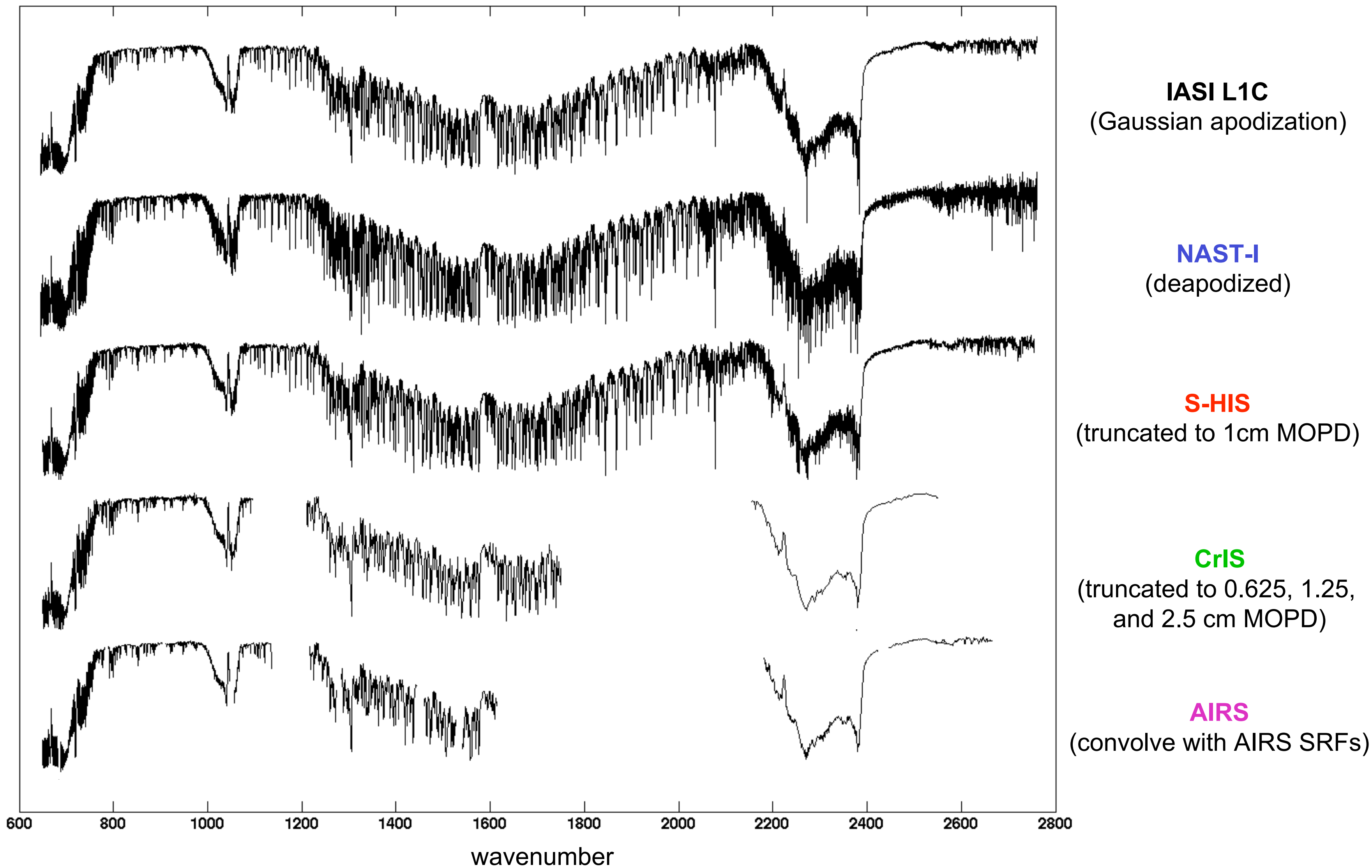
Sample IASI Level 1-C Spectra



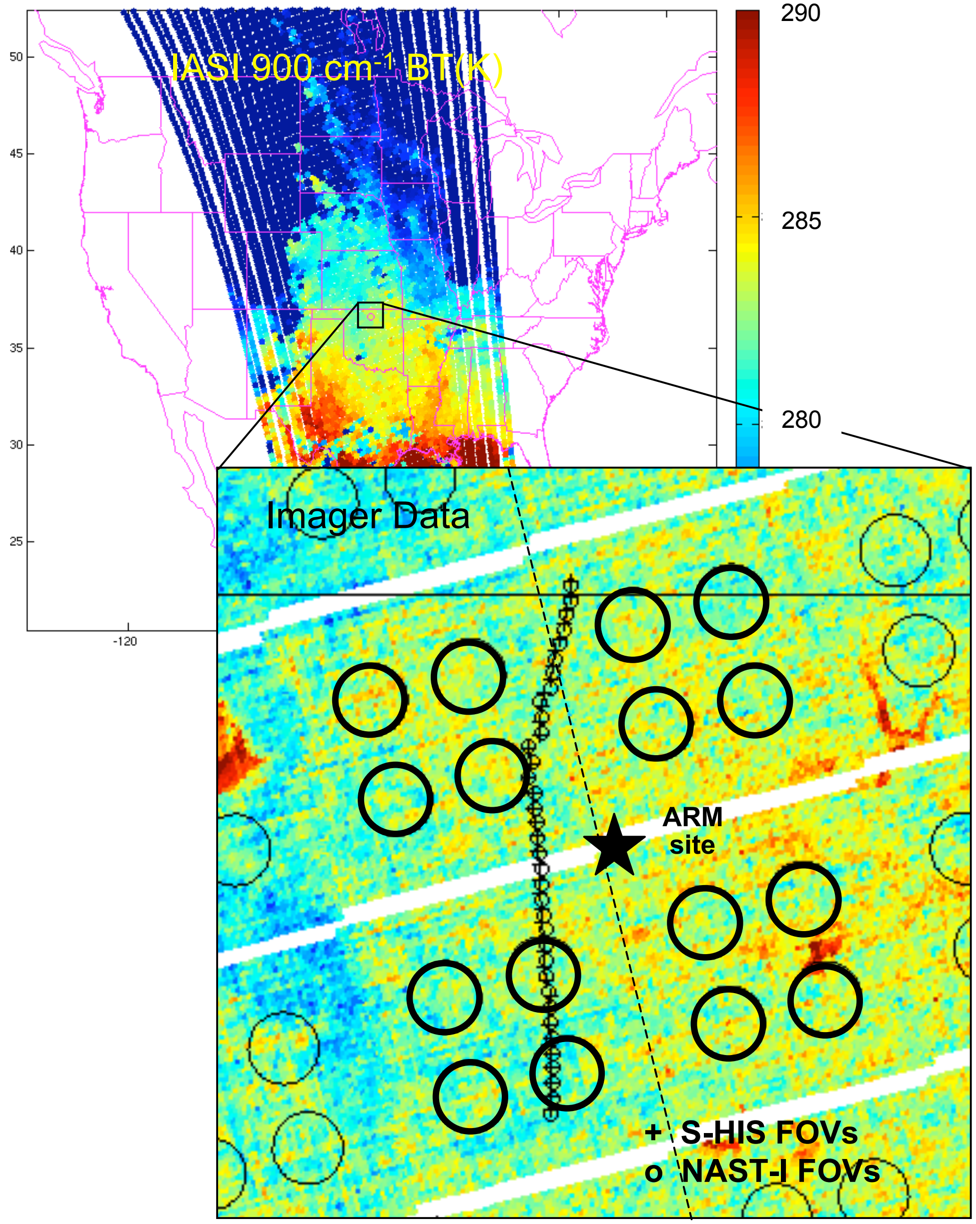
Level 1C (0.5 cm-1 Gaussian apodization, Nyquist sampled)
and PC noise filtered

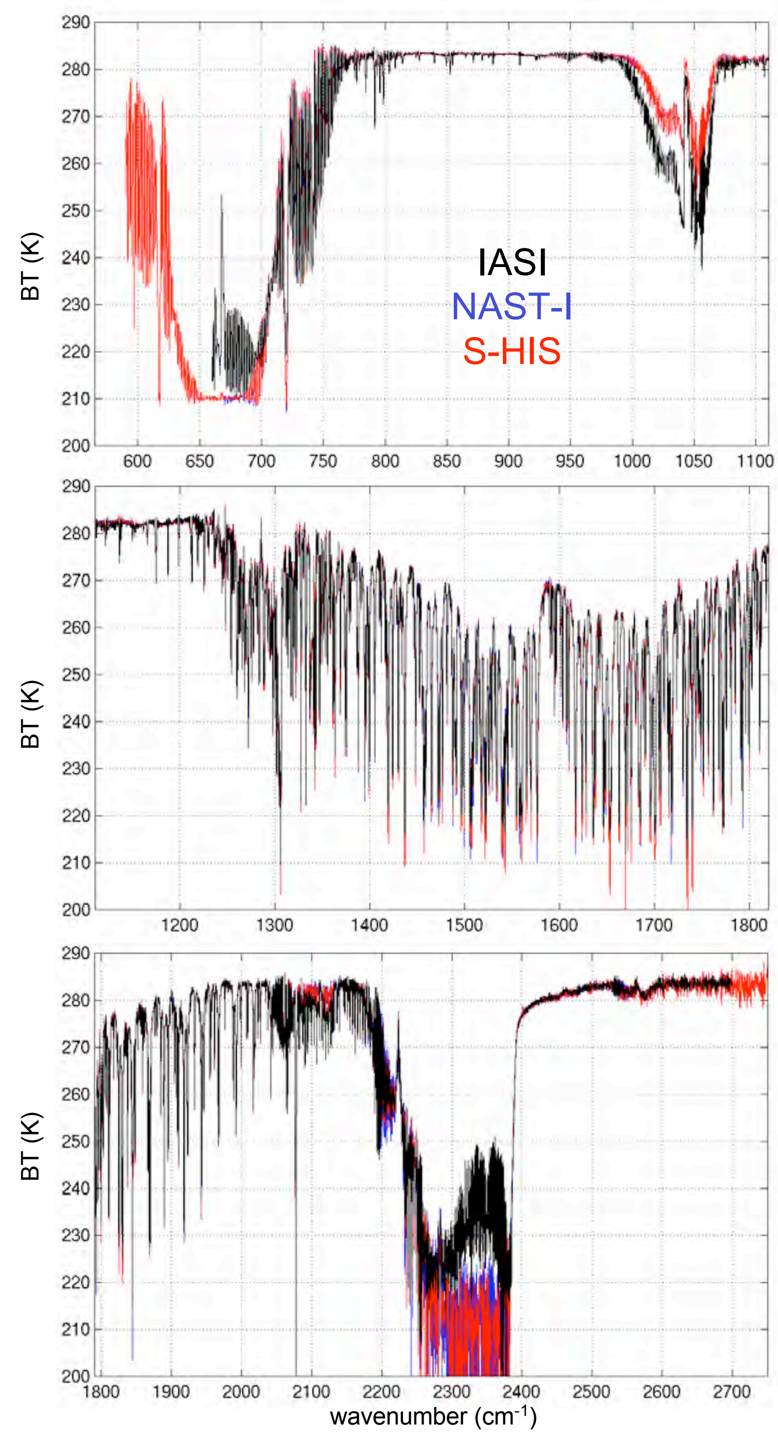


NAST-I, S-HIS, CrIS, and AIRS spectra simulated from IASI

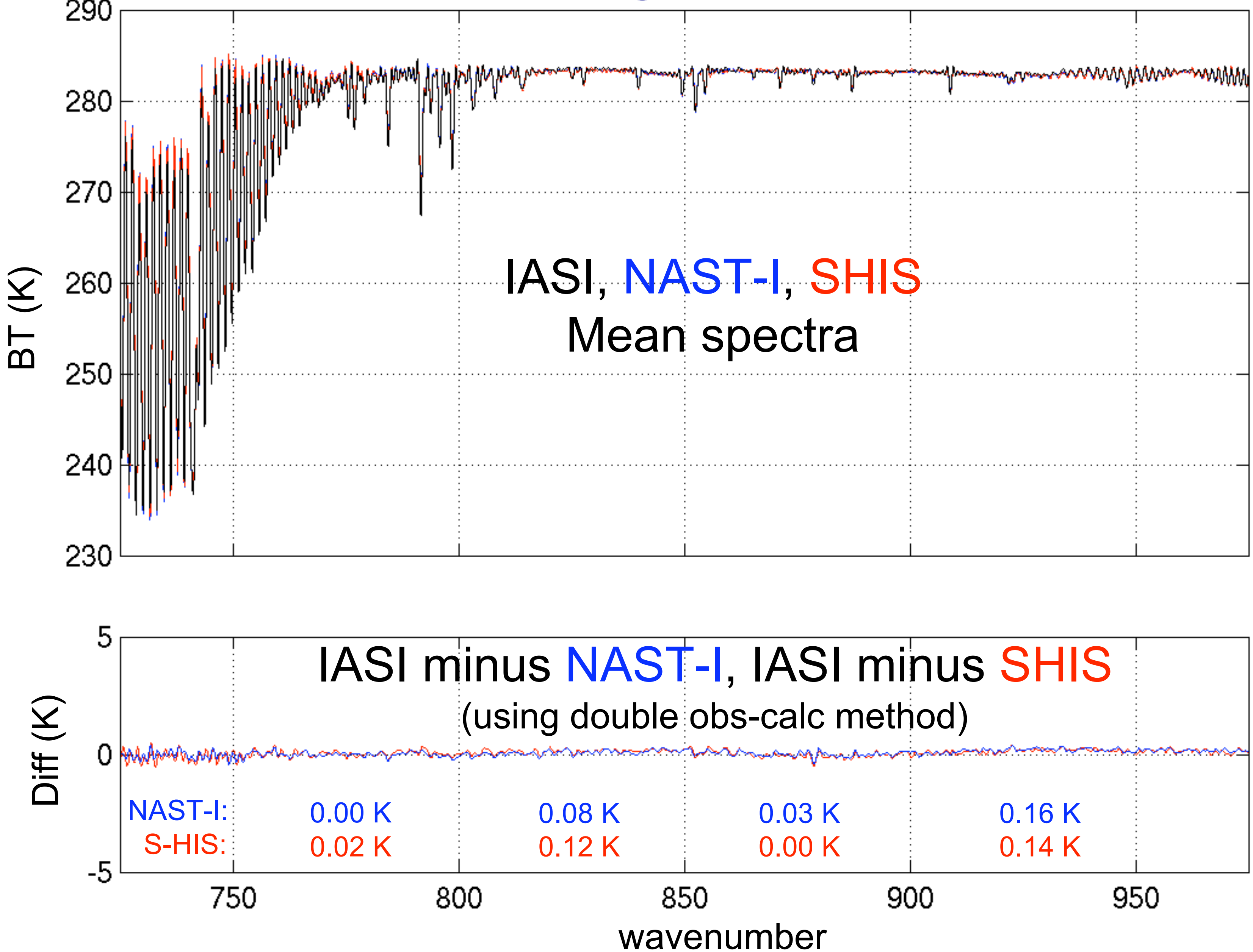


JAIVEx 19 Apr 2007 Case

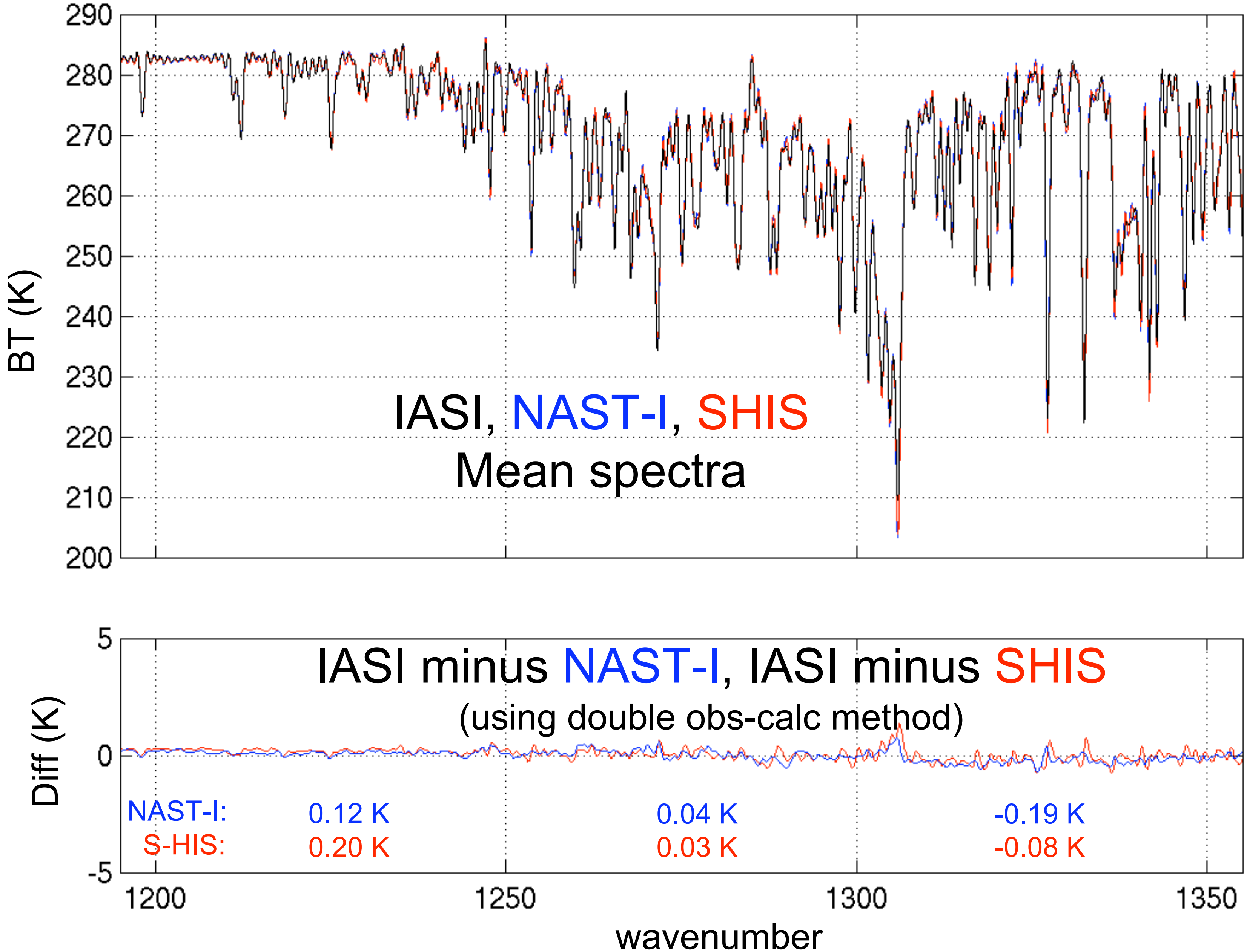




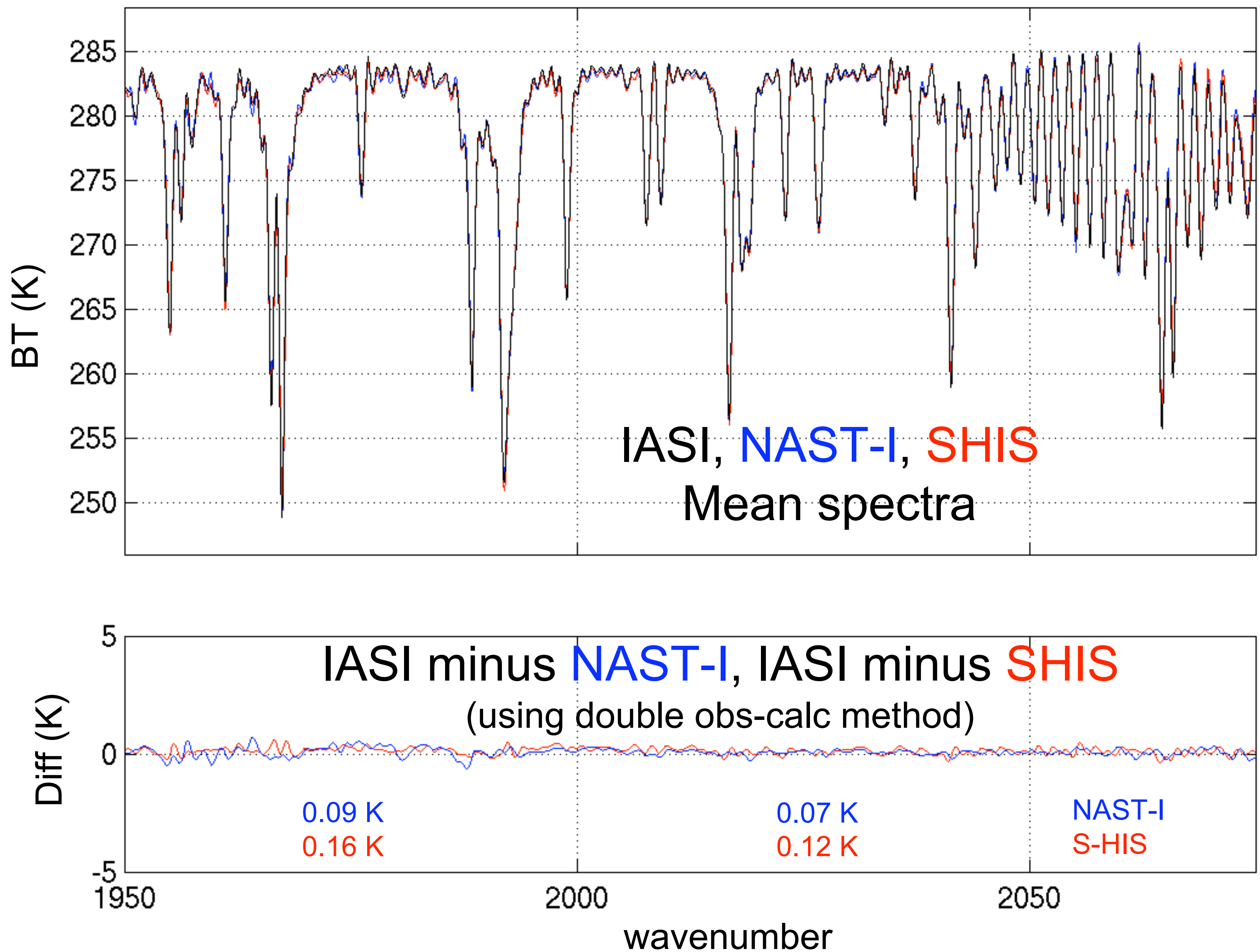
IASI Longwave Validation



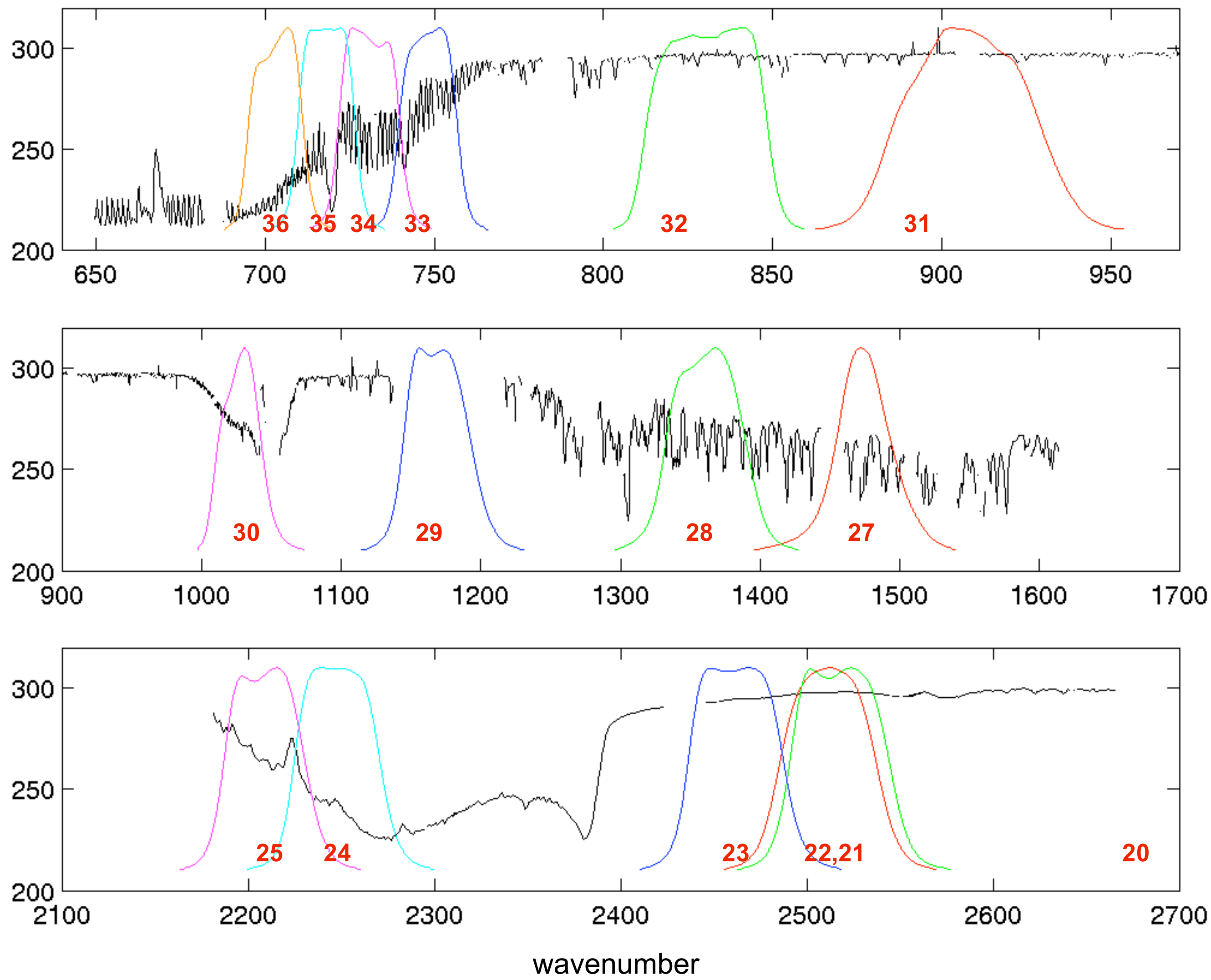
IASI Midwave Validation



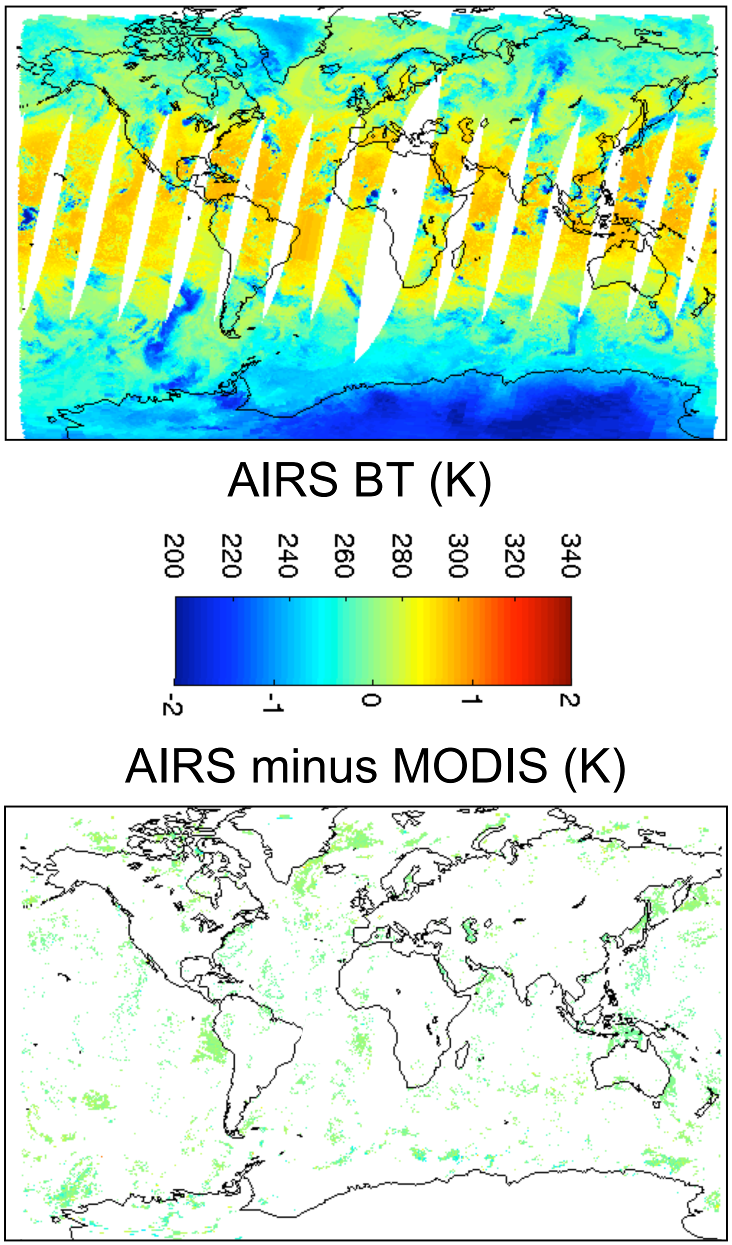
IASI Shortwave Validation

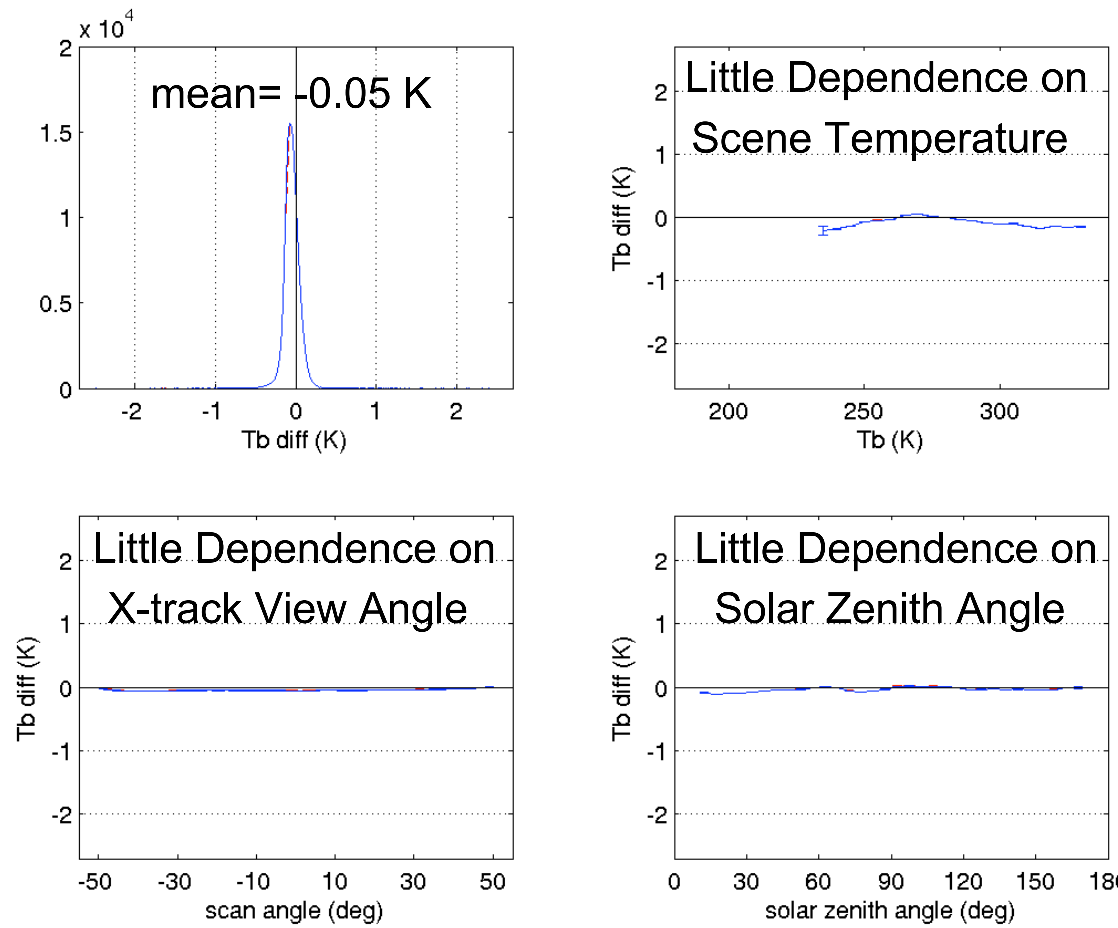


A sample AIRS brightness temperature spectrum overlaid with the Aqua MODIS Spectral Response Functions

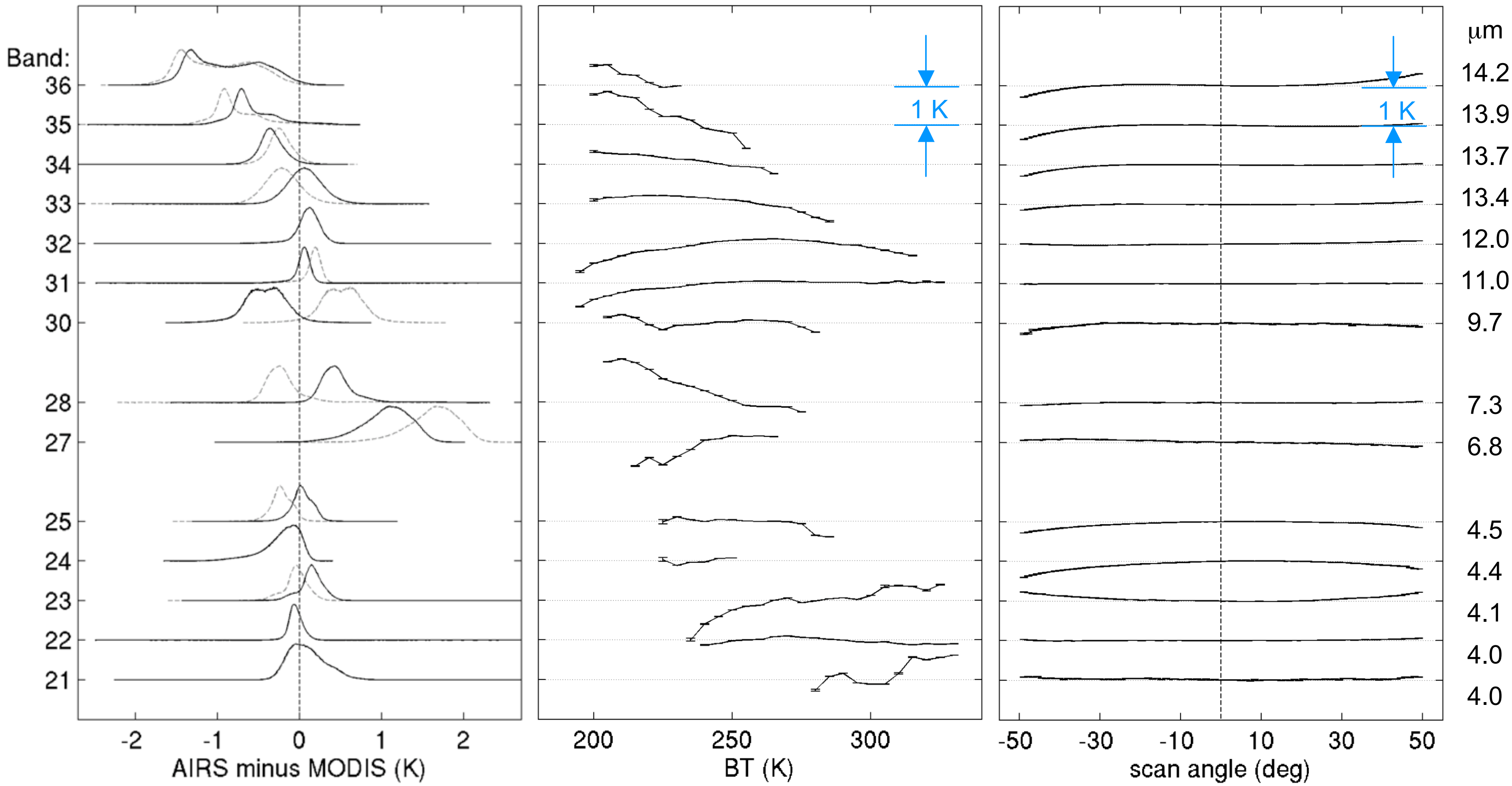


Example comparisons for band 22 (4.0 μm) on 6 Sept 2002

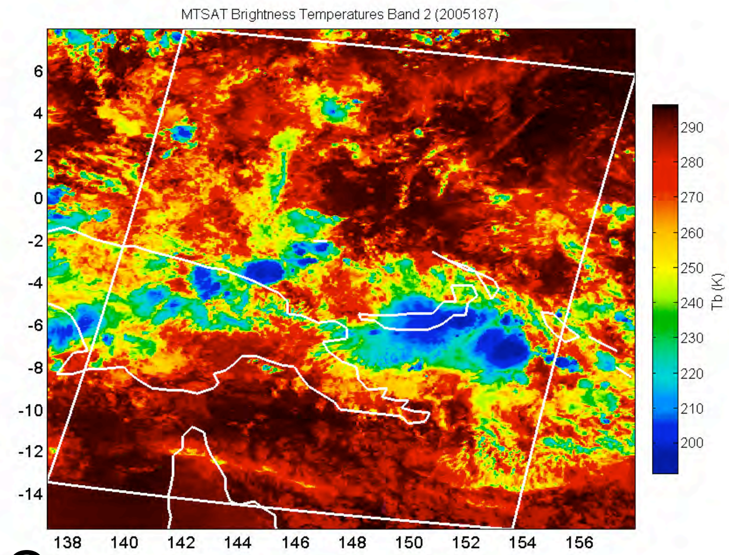


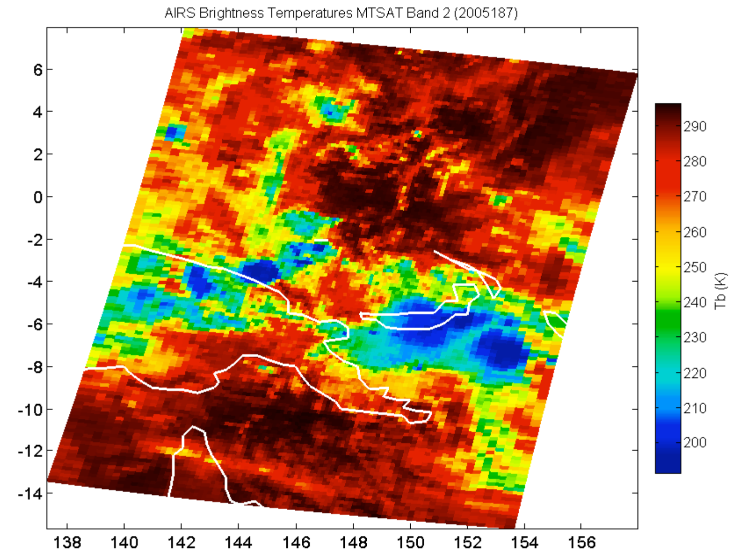


Distributions of differences and differences as a function of scene BT and scan angle



Intercalibrating Geostationary Imagers using a High-Spectral Polar Orbiter





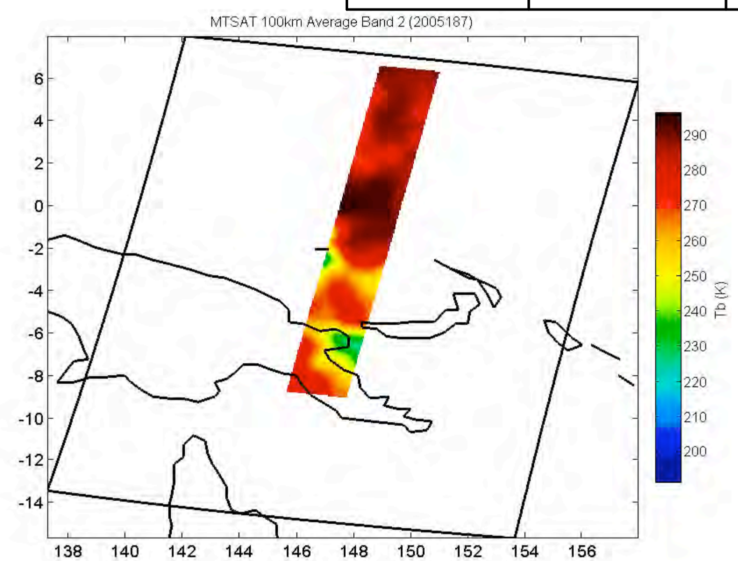
GEO

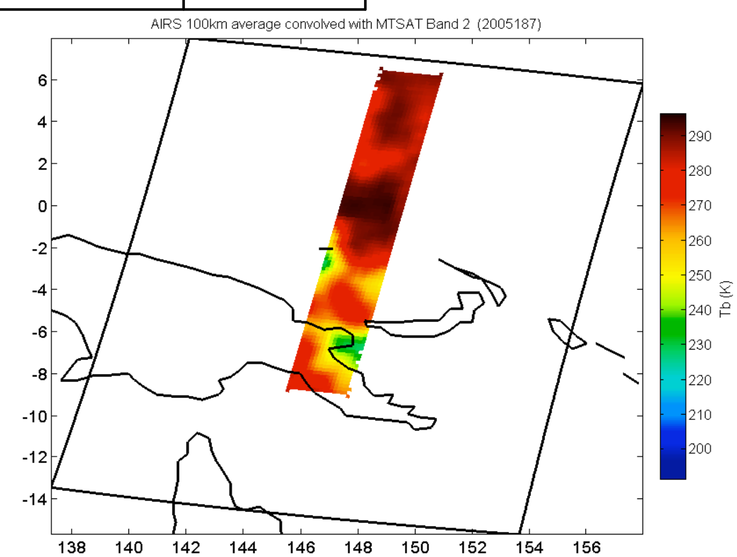
GEO-AIRS

Geo:	GOES-10	GOES-12	MET-8	MTSAT	GOES-9
N	17	52	68	13	65
ΔTbb (K)	-0.2	0.0	0.4	-0.4	-0.3
STD (K)	0.1	0.5	0.1	0.6	0.9

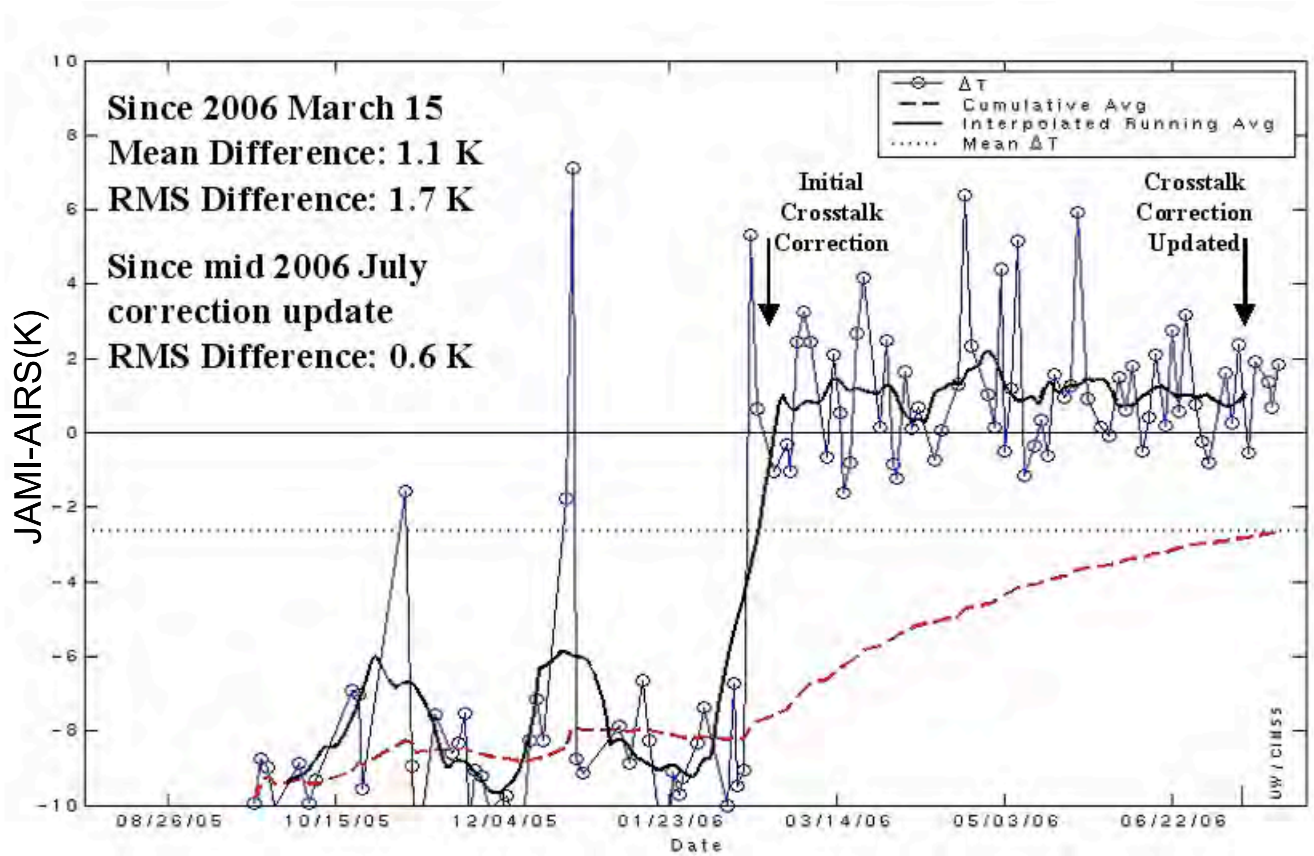
AIRS

11um band comparisons





MTSAT-1R (JAMI) IR4 (3.7μm) band compared to AIRS



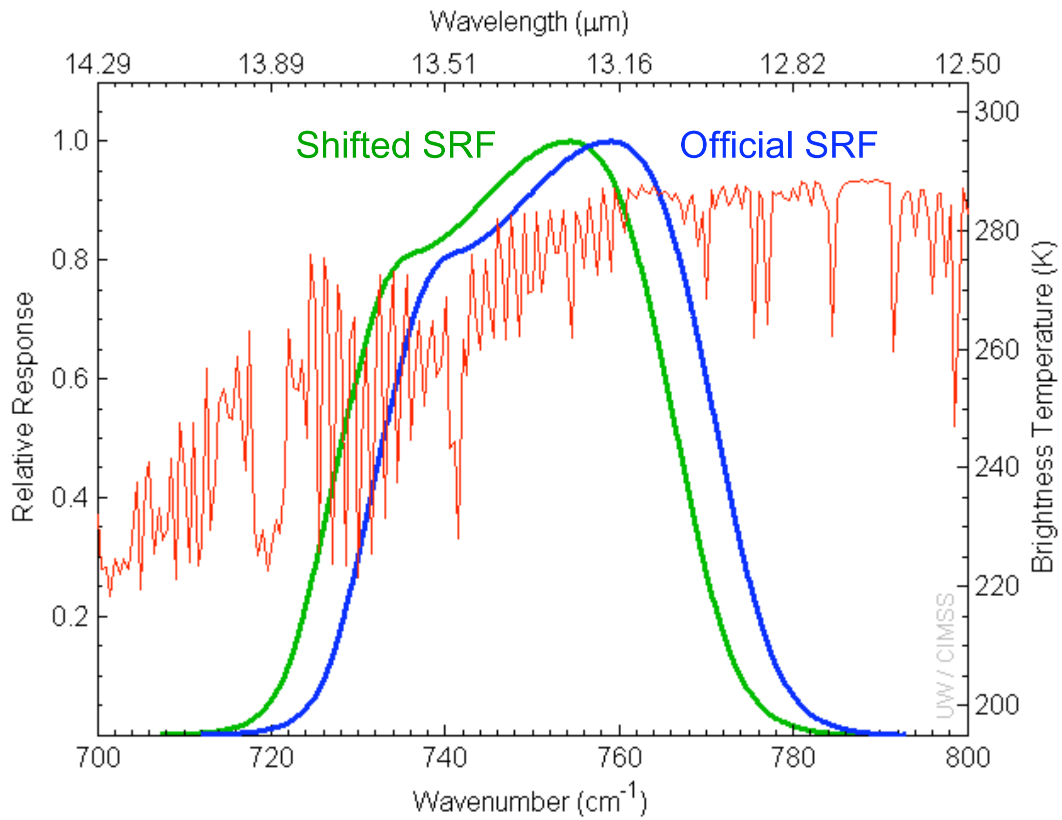
Quantifying Improvements through Intercal

Comparison of GOES-13 Imager to AIRS

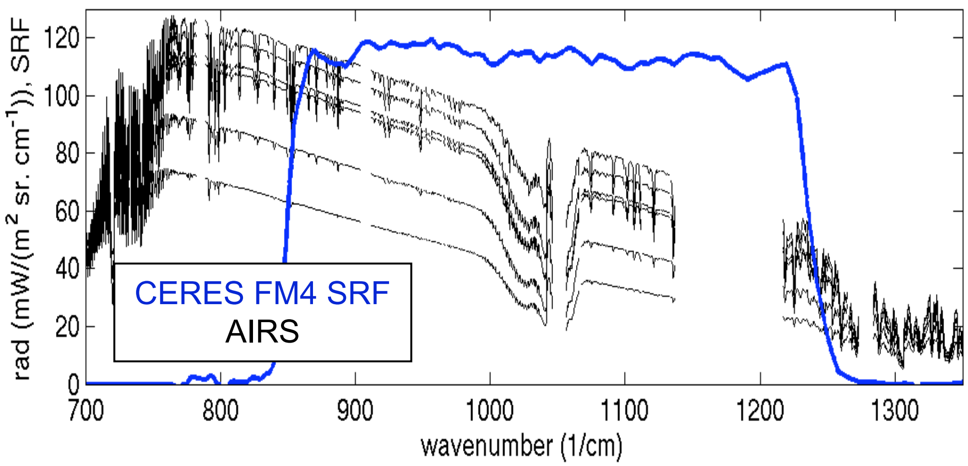
Imager Band	Mean Difference (GOES-AIRS) (K)	Standard Deviation of Differences (K)
2 (3.9 μm)	0.2	0.6
3 (6.5 μm)	-0.4	0.3
4 (10.7 μm)	-0.1	0.4
6 (13.3 μm)	**-2.4**	0.6

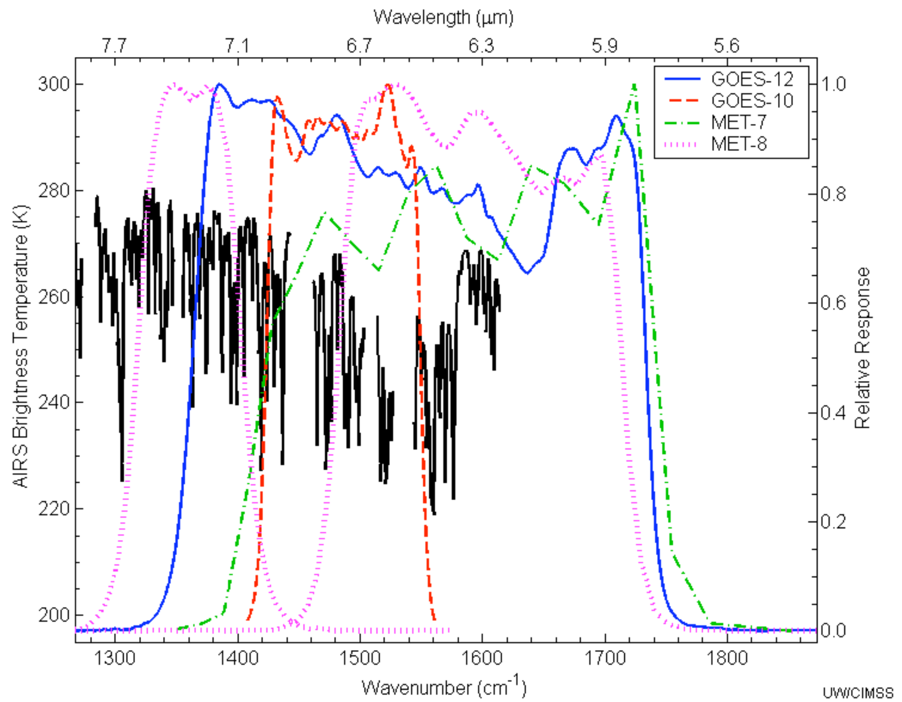
19 Comparisons during the GOES-13 Science Check-Out, December 2006.

- Shifting the 13.3um SRF by -4.7 wavenumbers reduced the mean difference with AIRS to **0.0 K**.
- This is technique can potentially be used to correct for calibration discrepancies.
- With an instrument such as AIRS, we have more accurate characterization of how well a sensor is calibrated, which allows us to (potentially) make calibration adjustments.



Importance of broad and continuous spectral coverage for intercal

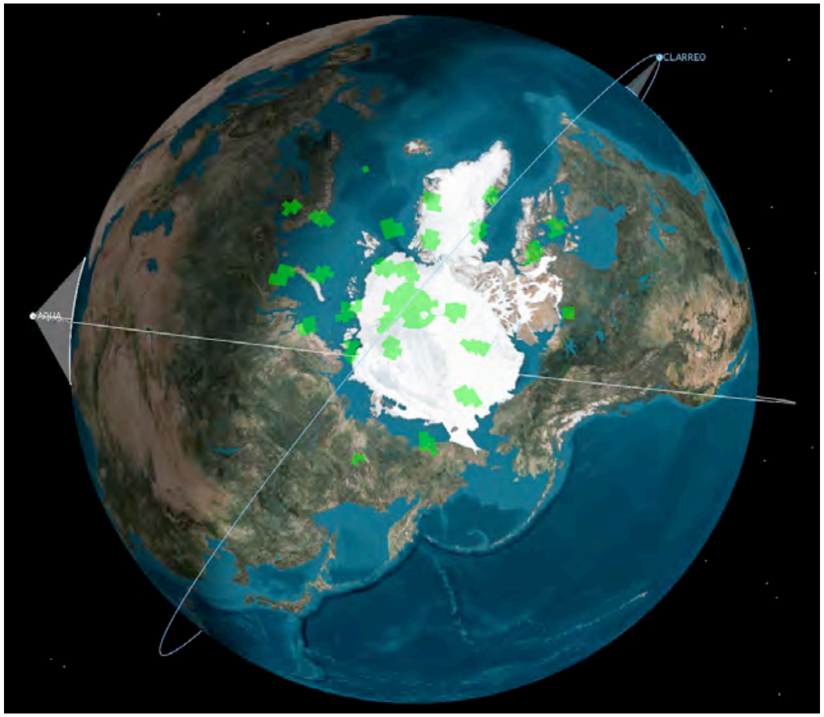




CLARREO Intercalibration Study

–*Given a CLARREO mission constellation selected for producing the primary CLARREO climate products, estimate the spatial and temporal colocation errors associated with performing intercalibration with a sun-synchronous sounder (CrIS or IASI) via SNOs*

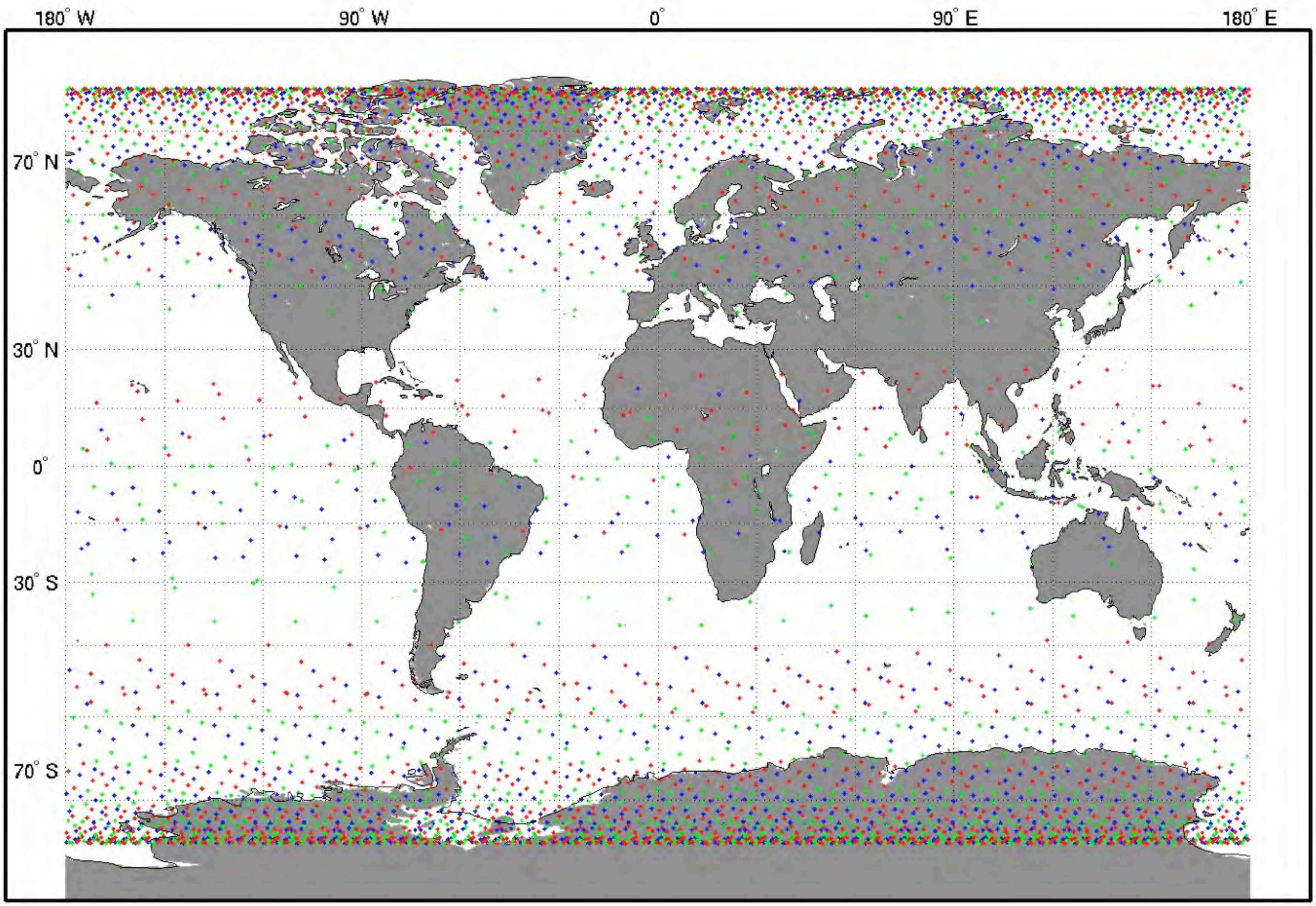
–*Estimate the CLARREO sensor noise required for accurate intercal via the same SNOs*



Methodology

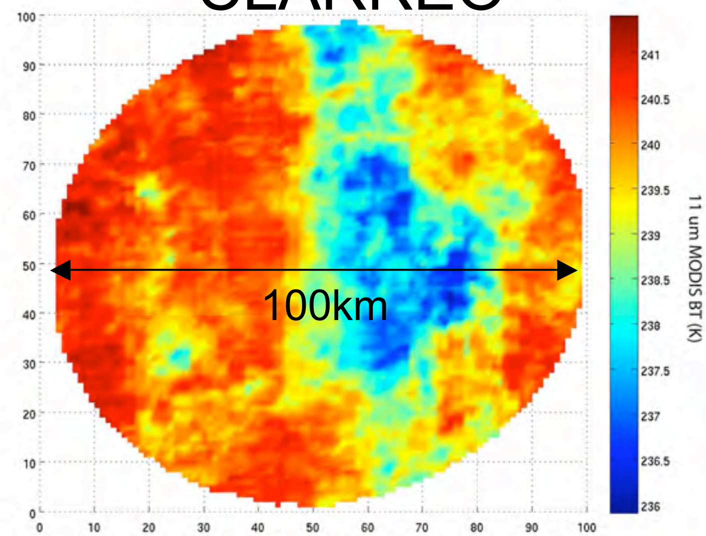
- Three 90-degree CLARREO orbits with right ascension separated by 120 degrees are simulated.
- SNOs between the simulated CLARREO and EOS Aqua are identified for the year of 2006.
  - Time differences up to 15 min
  - CLARREO nadir FOVs within 10 deg of Aqua nadir track (assumes corrections for <10 deg view angle differences, but those correction uncertainties not simulated or propagated here)
- CLARREO observation every N seconds
- 100 km diameter CLARREO obs are simulated as the mean of MODIS 11 um obs within the CLARREO FOV. STDDEV of MODIS within CLARREO FOV is also retained.
- Corresponding CrIS and IASI FOVs are also simulated, with their spatial sampling
- BT differences due to time differences between CLARREO and CrIS/IASI observation times are simulated with a spatial offset corresponding to a 30 mph wind and the difference in observation times.
- Character of the errors for monthly ensembles is examined.

Location of CLARREO/Aqua Intersections for the Year 2006

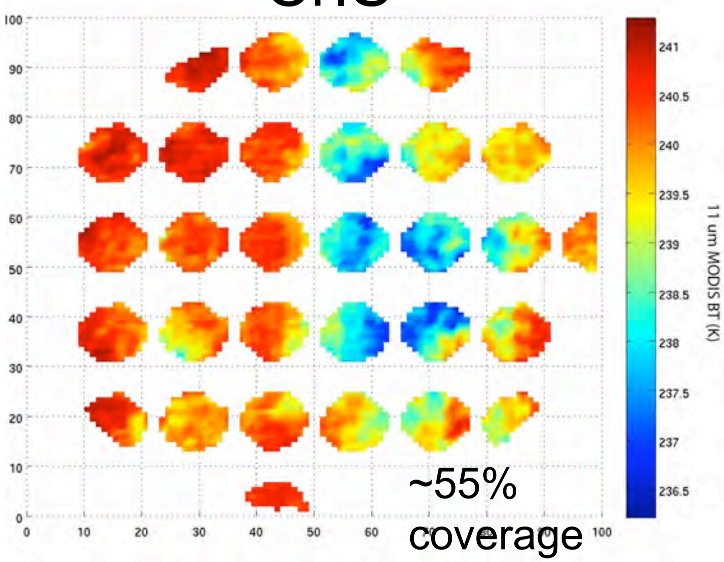


Spatial Sampling Differences

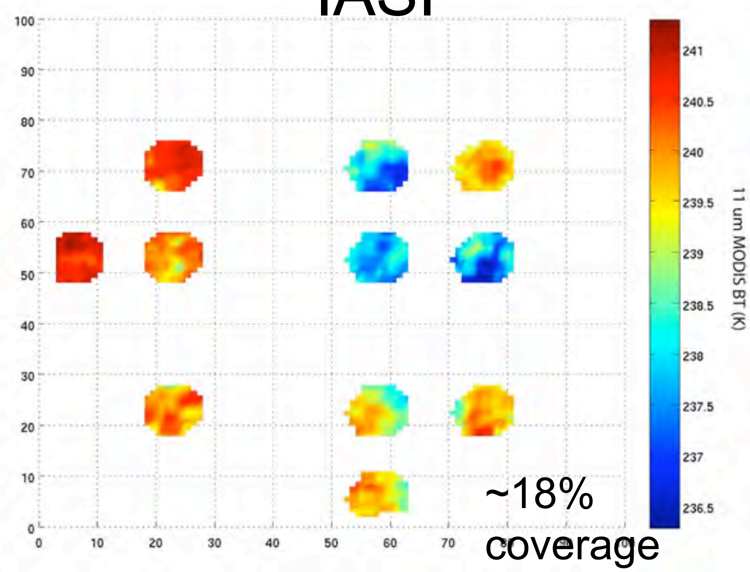
CLARREO



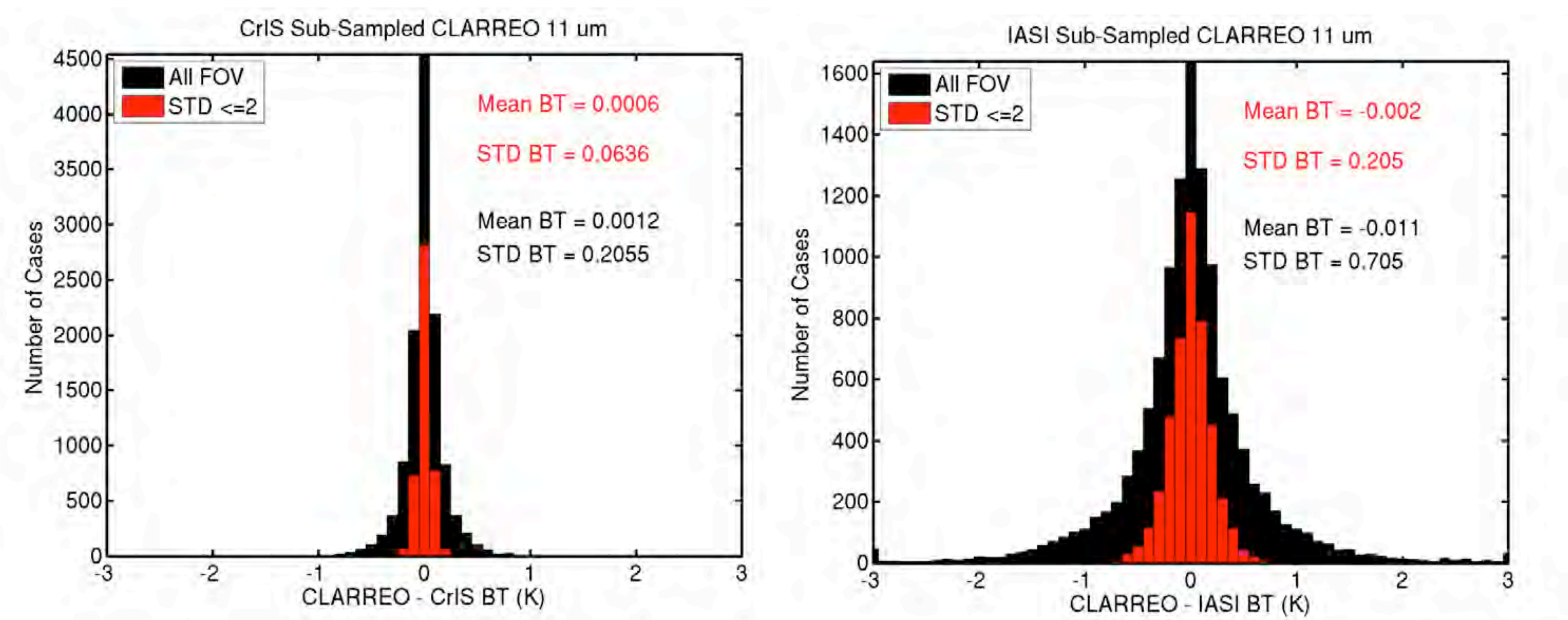
CrIS



IASI

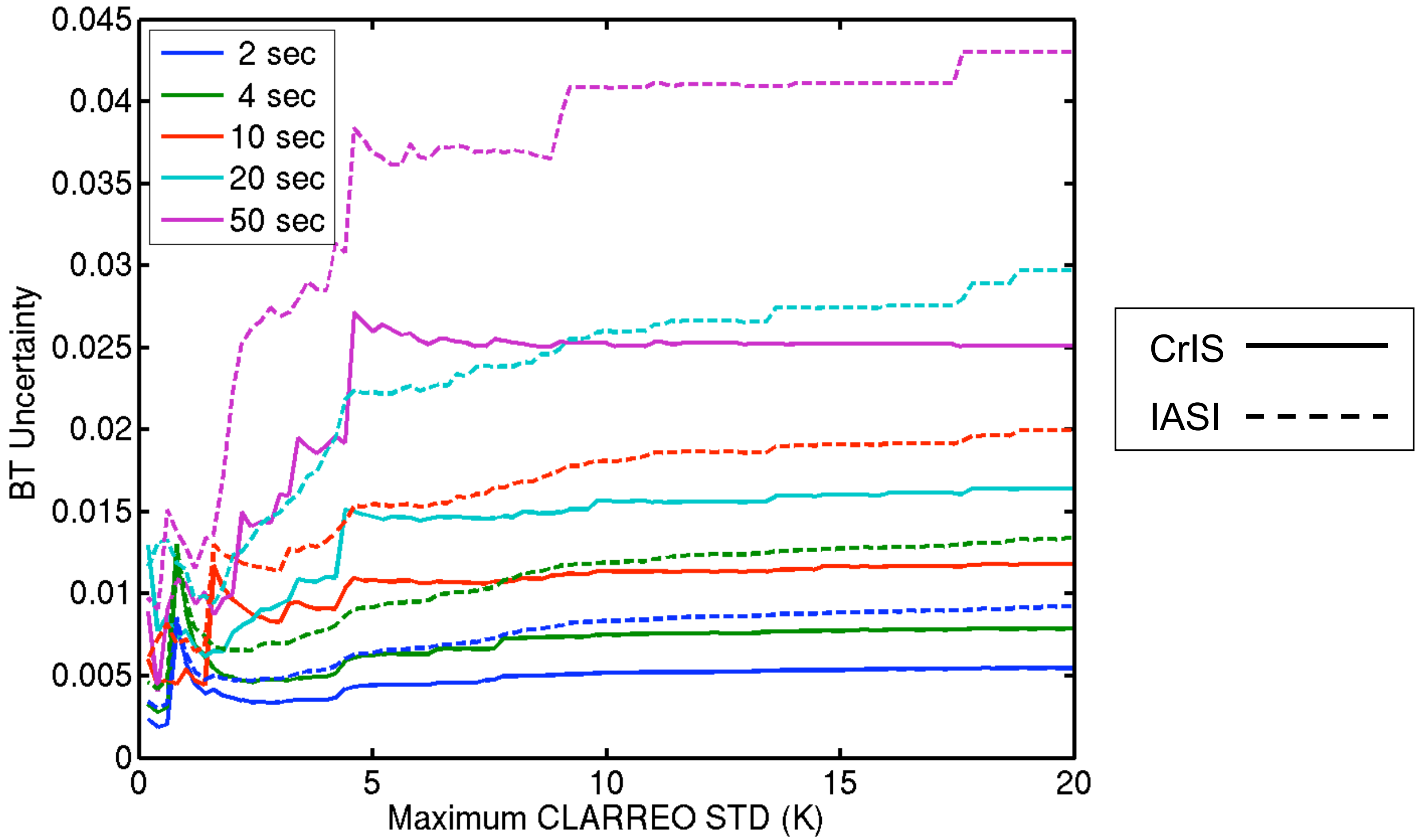


CLARREO - CrIS/IASI BT Differences Year of 2006

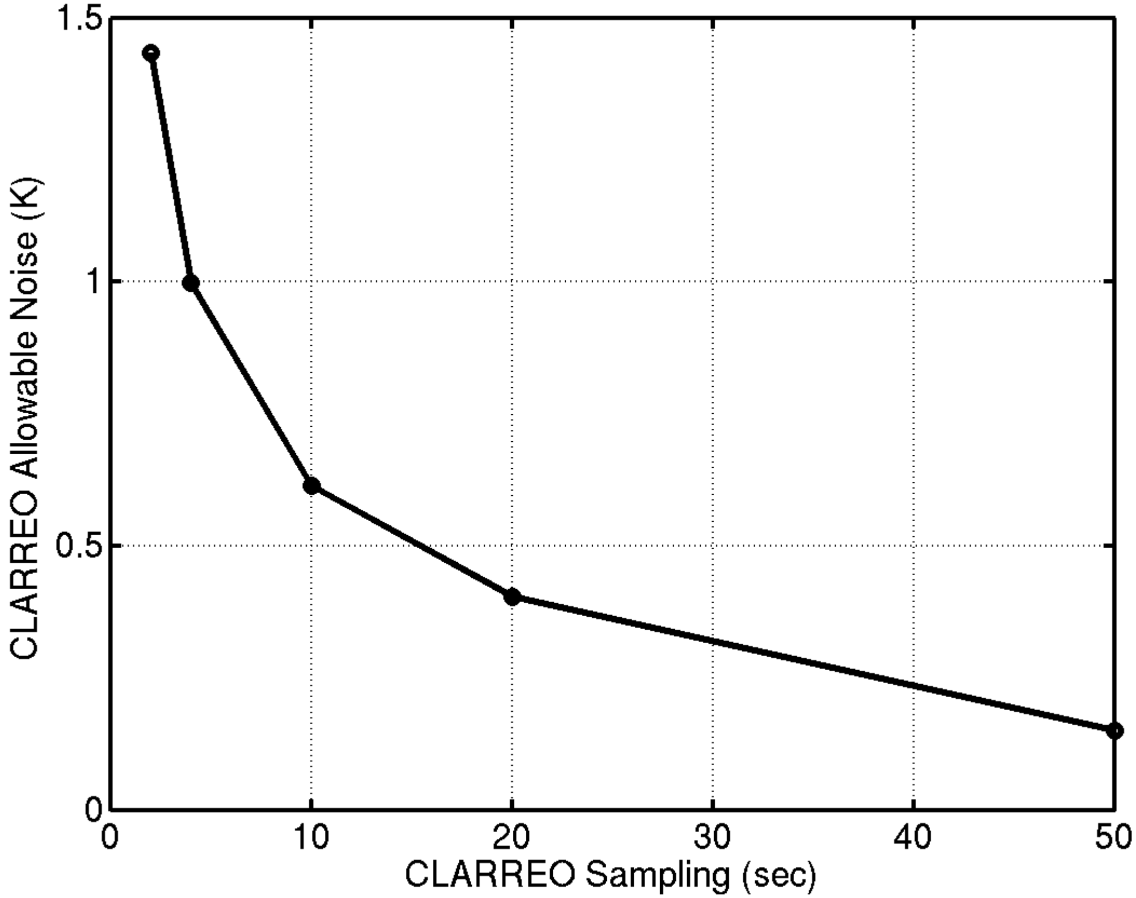


CLARREO sample every 10 seconds

Uncertainties in the monthly (Aug ‘06) mean biases due to simulated spatial and temporal colocation errors



Allowable single channel CLARREO noise for a monthly intercal uncertainty budget (space, time, IASI noise, CLARREO noise) of 0.03 K



Spatial STDDEV <= 2K

Summary / Conclusions

- By participating in periodic aircraft underflights, combined with the appropriate ground testing, we are working to provide traceable post-launch uncertainties for advanced sounder radiance observations.
- We are now frequently dealing with differences on the order of 0.1 to 0.2 K.
- There is a growing number of studies making use of the high spectral resolution AIRS data to evaluate broadband sensor calibrations
- For intercal, an on-orbit benchmark sensor should have broad and continuous spectral coverage
- Our CLARREO Intercal study suggests that a constellation of satellites orbits optimized for the primary CLARREO objectives also affords the cross-calibration with sun synchronous sensors with high accuracy
  - The majority of SNOs occur at high latitudes but are evenly distributed by longitude. The monthly distribution of 11 um BTs is peaked at 250 K but with a range of 220 – 300 K. Near nadir only.
  - The uncertainty in the monthly mean difference between CLARREO and sub-sampled sounder BTs decreases as a function of the spatial standard deviation threshold
  - Using CLARREO FOVs with spatial standard deviations less than ~3K, the uncertainty in the monthly mean BT differences due to differences in spatial and temporal sampling are less than 0.02 K.
  - To meet a monthly inter-calibration uncertainty of 0.1 K 3-sigma, the required single channel noise for CLARREO is approximately 0.6 K for 10 second sampling, with no assumed spectral averaging.
  - The results do not vary significantly by month.